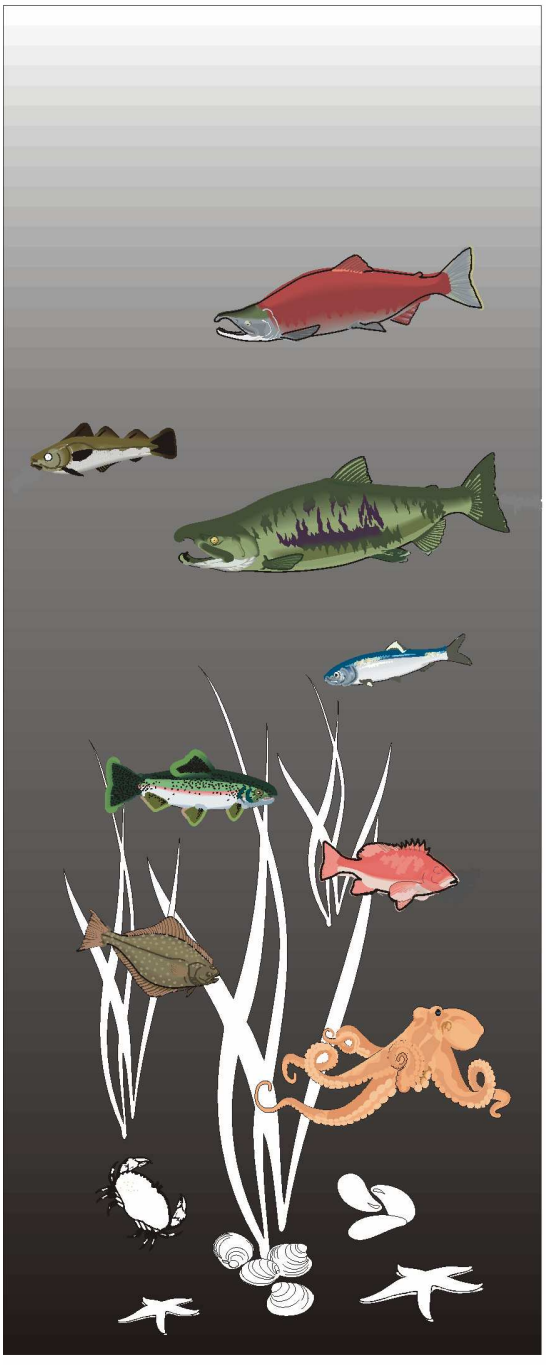
Northwest Fishery Resource Bulletin



Coho Salmon Escapement to the Skagit River Estimated Using a Mark-Recapture Method: 1987

By

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Project Report Series No. 7

Northwest Fishery Resource Bulletin

Project Report Series

The Northwest Fishery Resource Bulletin presents the results of investigations carried out by the Washington Dept. of Fish and Wildlife, Western Washington Treaty Tribes, and/or the Northwest Indian Fisheries Commission that are deemed of sufficient interest to be made available to the scientific community and the public.

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ABSTRACT

Since 1965, an index live-count method has been used to annually estimate the number of coho salmon in the escapement to the Skagit River. The accuracy and precision of the estimates from this method have never been critically examined. A five-year project to examine alternative methods of estimating the number of wild coho salmon in the escapement to the Skagit River began in 1986. In addition to the index live-count method, three other methods of estimating the coho salmon escapement to the Skagit River were examined: (1) a mark-recapture method; (2) a redd-count expansion method; and (3) a method based on estimates of the proportional contribution of hatchery-produced coho salmon to the total escapement. **This report documents the results of the mark-recapture portion of the project for 1987.**

In 1987, coho salmon were captured with a beach seine between river miles 32 and 38 of the Skagit River from 3 September through 20 November. A total of 5,425 coho salmon were tagged with a jaw tag and marked with opercula punches. Tags were recovered during surveys designed to randomly sample the coho salmon escapement. Samples were collected at 13 areas in the Skagit River drainage: Marblemount Hatchery; Baker River trap; spawning grounds in the Middle Skagit, Upper Skagit, Lower Sauk, Middle Sauk, Upper Sauk, Suiattle, Cascade, Nookachamps, and Carpenter sub-basins; and in commercial and test fisheries. A total of 45,307 coho salmon were examined of which 45,286 fish were considered in-sample and 21 were not considered part of the population subject to tagging.

A total of 1,366 tagged or marked coho salmon were recovered during in-sample surveys. The tag recovery data indicate that approximately 3% of the coho salmon migrating through the tagging area in the lower Skagit River were caught and tagged. The percentage of tagged or marked coho salmon in the samples from nearly all the major recovery areas (areas with seven or more tag recoveries) was near 3%: Marblemount 3.3%; Baker River trap 2.7%; commercial fishery 3.2%; Middle Skagit sub-basin 3.4%; Suiattle sub-basin 3.6%; Lower Sauk sub-basin 2.6%; and Upper Sauk sub-basin 3.4%. The exceptions were the samples from the Upper Skagit sub-basin (4.1%), Middle Sauk sub-basin (2.2%), and Cascade sub-basin (1.5%). The tag recovery data indicate that some coho salmon from spawning areas substantially downstream of the tagging site were present in the tagging area. There were eight tags recovered in 1,508 coho salmon examined (0.5%) during spawning ground surveys in the Nookachamps and Carpenter sub-basins.

The estimated abundance of coho salmon in 1987 was 167,408 fish with a 95% confidence interval of 158,694 to 177,368 fish. This estimate is for the number of coho salmon migrating through the tagging area after tagging began on 3 September. It includes all coho salmon bound for spawning areas above the tagging area and an unknown fraction of the salmon from spawning areas in the Nookachamps and Carpenter sub-basins. This abundance estimate was very precise (CV = 2.5%) because of the large number of fish tagged and the large number of fish examined for tags during in-sample surveys. To restrict the estimate to spawning areas in the Middle Skagit sub-basin and spawning areas above it, adjustments were made to the number of tags released. Using the adjusted number of tags released, the estimated abundance for this more restricted area was 166,020 coho salmon. **The total return of coho salmon to Skagit Bay in 1987 is estimated to be 180,706 fish. There were an estimated 137,738 naturally-spawning coho salmon in the escapement to Skagit River spawning grounds**: 133,088 fish were estimated to have reached upstream spawning grounds and 4,650 coho salmon were estimated for lower river (Nookachamps and Carpenter sub-basins) spawning grounds (see summary table on the next page).

Table summarizing the total return of coho salmon to Skagit Bay in 1987 by major components.

Component	Number of Fish
Total Terminal Run Size	180,706
Marblemount Hatchery	29,277
Baker River Hatchery	1,576
Commercial Fishery Catches	10,749
Test Fishery Catches	1,366
Subtotal	42,968
Wild Escapement	
Upstream Areas	133,088
Lower Areas	4,650
Subtotal	137,738
Sport Catch[a]	129

[a] An unknown portion of the sport catch should be subtracted from the wild escapement and the remainder added to the total terminal run size.

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INTRODUCTION

The Skagit River is the largest river system in the Puget Sound region. It has 162 miles of mainstem river and its headwaters are in Canada (Figure 1). This system is one of the largest producers of coho salmon (*Oncorhynchus kisutch*) in northern Puget Sound. Coho salmon from the Skagit River are caught in fisheries from Northern California to Southeast Alaska and are a major contributor to fisheries in the inside marine waters of Georgia Strait and Puget Sound (PFMC 1992). The Skagit River is managed for natural production of coho salmon (subsequently referred to as wild coho salmon). In years when the numbers of wild coho salmon projected to return to the Skagit River are small, fisheries from Cape Falcon, Oregon to the US/Canada border have been constrained to protect these fish (PFMC 1986, pg. III-9; and PFMC 1988, pg. III-11). Accurate annual assessments of stock status are required for coho salmon from the Skagit River because this stock can affect the management of fisheries over such a large geographic area. This ensures that fisheries are not unnecessarily restricted during years when there is not a conservation problem and prevents over-harvest of wild coho salmon from the Skagit River during years of small returns. An important component of the information needed to accurately assess the status of wild coho salmon from the Skagit River is an annual estimate of the number of coho salmon in the spawning escapement. Spawning escapement, as used in this report, refers to the number of adult coho salmon which are present in all natural spawning areas of the Skagit River and have the potential to spawn in these areas. It does not include coho salmon returning to Marblemount Hatchery or to the release site for hatchery-produced coho salmon at the Baker River dam.

Since 1965, the Washington Department of Fish and Wildlife (WDFW) has used an index live-count method to annually estimate the escapement of coho salmon to the Skagit River (Flint 1983). The accuracy and precision of the estimates from this method have not been critically examined. A five-year project to examine alternative methods of estimating the number of wild coho salmon in the spawning escapement to the Skagit River was begun in 1986. This project was conducted by the Skagit System Cooperative (SSC) in cooperation with personnel from WDFW and Puget Power and Light. Three methods of estimating the spawning escapement of coho salmon to the Skagit River were examined: (1) a mark-recapture method; (2) a redd-count method; and (3) a method based on estimates of the proportional contribution of hatchery-produced coho salmon to the total escapement.

This report is the second in a series of reports that will document the studies conducted from 1986 through 1990 which examined different methods for estimating the escapement of coho salmon to the Skagit River. The 1986 study is summarized in Conrad et al. (1997). **This report summarizes the data and documents the results of the mark-recapture portion of the project for 1987.** Reports documenting the results for the other years that tagging was conducted (1988, 1989, and 1990) and the other methods of estimation will follow. Some summary data from the other years of the study are used to support some of the assumptions required for the analysis of the tagging data from 1987. These data are documented in Conrad et al. (1997).

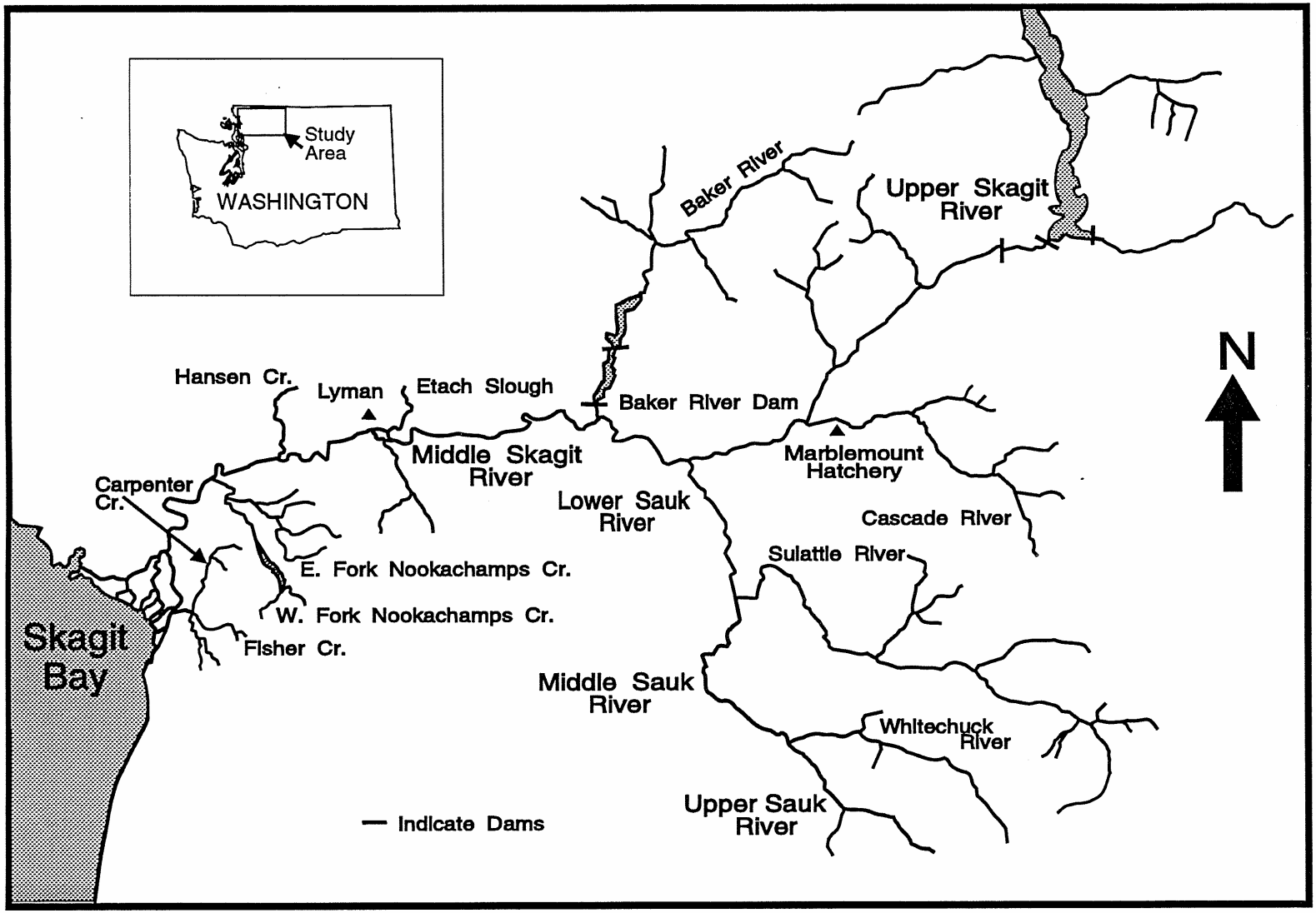

Figure 1. Map of the Skagit River system showing the location of the areas where tag recovery surveys were conducted.

METHODS

The description of methods is divided into four sections. The first section describes the methods used to capture coho salmon for tagging and the tagging procedure. The second section describes the surveys used to recover tags. This includes a description of the survey procedures for each of the tag recovery areas. Section three summarizes the statistical procedures used to estimate the abundance of coho salmon from the tag release-and-recovery data. The last section describes some miscellaneous analyses conducted to examine migration timing and the sex and length composition of the coho salmon that were sampled.

Tagging Methods

Beach Seining:

Coho salmon were captured for tagging using a beach seine operated by a five-man crew. Seining was conducted at two sites in an area between river mile (RM) 34 and RM 36 of the Skagit River (Figure 2). A 3″-mesh, monofilament beach seine that was 240′ long by 20′ deep was used to capture coho salmon. The net had a 36′ bunt made of 2″ knotless seine material. Cork spacing was 8″ on the bunt and two feet on the rest of the net; the leadline was hung with 15 lb per 60′ of net. Modifications in net dimensions occurred whenever the seine was damaged. Due to heavy use, the leadline was rehung about every four fishing days and the monofilament was replaced after every eight to ten fishing days.

A boat was used to set the beach seine. One end of the seine was held by two crew members on a gravel bar while the boat backed away from the shore and the net was set off the bow of the boat. When the entire net was out, the boat-end of the net was towed downstream. The other end of the net was attached to a four-wheel drive truck and driven slowly downstream. Care was taken to prevent the shore-end of the net from getting ahead of the boat because fish tended to lead away from the shore and around the boat. During the drift, a seine plunger (a long pole with a cup on the end) was slammed into the water periodically to drive fish away from the river-end of the net and toward the shore. At a pre-designated point the boat returned to the gravel bar. Upon reaching the shore, the boat-end of the net was attached to the back of a second four-wheel drive truck. Both trucks then pulled the net up the gravel bar, perpendicular to the river, until only the bunt end of the net was in the water. The five-man crew then pulled the bunt in by hand until the leadline was on shore while the cork line and ends were cradled by the crew.

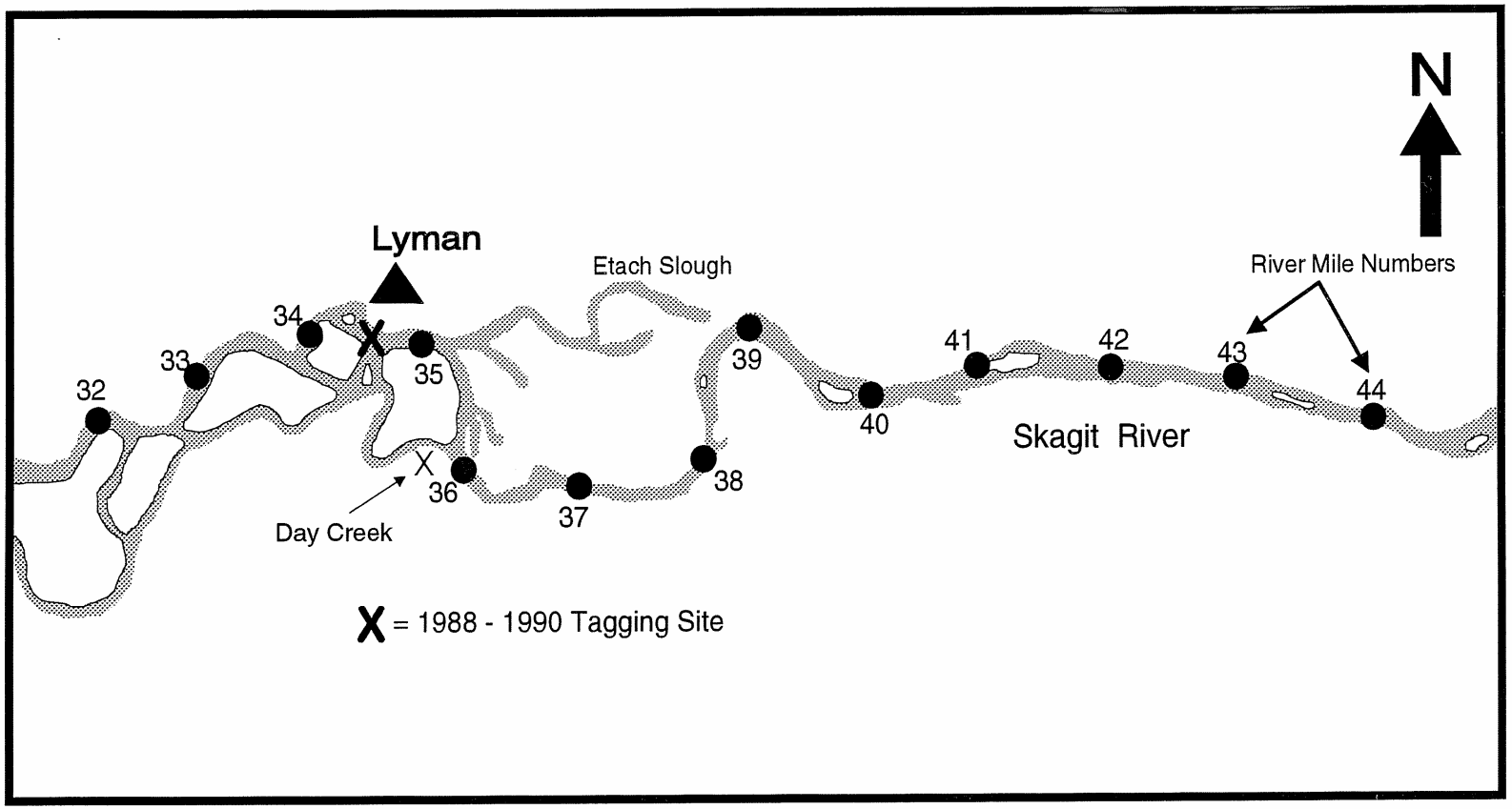

Figure 2. Map of the area of the Skagit River where coho salmon were captured and tagged, 1986-1990. Tagging in 1987 was primarily conducted at Lyman but six coho salmon were tagged at Day Creek.

Tagging Procedures:

Coho salmon were removed from the bunt and placed into either of two net pens adjacent to the capture site. All other species were counted and returned to the river. The pens were 3′ by 5′ by 5′, constructed of PVC, and covered with 0.5″ knotless nylon mesh. Each coho salmon was taken from a net pen by a sampler wearing cotton gloves and placed on a V-shaped measuring board lined with high-density foam. A sequentially-numbered hog ring was clamped around the lower left mandible of each fish using a pair of hog-ring pliers and a 3/8″ hole was punched in the rear center of each gill operculum with a paper hole-puncher. The fork length (measured to the nearest cm), sex of the fish, any external marks, and a qualitative assessment of maturity (bright, blush, or dark) were recorded for each fish with the date and tag number. Each tagged salmon was held gently in the water until its equilibrium was regained before being released. If a tagged fish did not swim away or appeared to be injured it was given a condition rating of "X-". Fish that swam away normally were given a condition rating of "X". If a fish was especially vigorous when released a condition rating of "X+" was assigned. Fish with severe physical impairments (e.g., 50% scale loss, torn opercula, deep predator wounds) were released untagged. These included jack coho salmon (male salmon under 30 cm in length) which generally gilled in the net and were unfit for tagging.

Tag Recovery Surveys

Only tags recovered during surveys designed to randomly sample the coho salmon escapement were used for the abundance estimates. These are referred to as **in-sample recoveries**. Tag recovery surveys were conducted by sampling: (1) all fish spawned, surplused, or otherwise sacrificed at Marblemount Hatchery; (2) all fish caught at the fish trap at Baker River dam; (3) the catch by the in-river commercial fishery; (4) all test fishery catches; (5) every reachable and identifiable dead coho salmon found during spawning grounds surveys; and (6) every coho salmon caught in traps operated on: Fisher Creek and Carpenter Creek Slough (tributaries to Carpenter Creek); the East Fork of Nookachamps Creek; Hansen Creek (a tributary to the Middle Skagit sub-basin); and Barnaby Slough (a tributary to the Upper Skagit sub-basin). During each survey or day of trap operation, the date, number of coho salmon inspected for tags, number of tagged or marked (with the opercula punches) fish found, and tag numbers of all coho salmon recovered with legible jaw tags were recorded.

Marblemount Hatchery:

Samples were collected by three different methods at WDFW's Marblemount Hatchery: spawned fish, surplused fish, and pond mortalities. After any processing, hatchery personnel sorted the fish from these groups into separate bins for tagged/marked and unmarked fish. SSC crews then re-checked these bins for coho salmon with tags or marks. The date of sampling, number of coho salmon inspected for tags, number of tagged or marked fish found, and tag numbers of all coho salmon recovered with legible jaw tags were recorded.

Coho salmon were spawned at Marblemount Hatchery to meet specific egg-take goals. Spawning was conducted when the portion of the run from which eggs were desired was present and there were large numbers of fish in the holding ponds. Hatchery personnel selected fish for spawning and sorted them into the bins after spawning for SSC crews to examine. Surplused fish were those in excess of the spawners needed for eggs. Surplus coho salmon were periodically sacrificed and sorted into the bins. The holding pond was periodically surveyed for mortalities and any dead coho salmon were removed and sorted into the bins. A schematic of the Marblemount Hatchery sampling procedure is shown in Figure 3.

Except for the pond mortalities, hatchery personnel selected the coho salmon for the other two groups, spawned and surplused, according to a visual assessment of the fish and the timing of the return to Marblemount Hatchery. Therefore, these fish were not strictly sampled at random and the percentage of tagged fish in these samples might have been influenced by the selection process. However, since all coho salmon returning to the hatchery were eventually sampled, the Marblemount Hatchery sample was a census and the sample total for the entire spawning season provided the best estimate of the percentage of tagged coho salmon at Marblemount Hatchery.

Baker River Trap:

A fish trap at Baker River dam caught all upstream migrating salmon. All coho salmon caught at the trap were examined. Fish caught in the trap were crowded into a brail and several removed at a time onto a sorting table. Each coho salmon was examined for a tag or mark. The sample date, condition, and tag number (when legible) were recorded for any jaw-tagged or opercula-punched coho salmon. After all live fish in the brail were removed, the racks and screen of the trap were searched for dead fish. Therefore, identically to the Marblemount Hatchery sample, the Baker River trap sample was a census and the sample total for the entire spawning season provided the best estimate of the percentage of tagged coho salmon at the Baker River trap.

The Baker River stock is one of the earliest returning coho salmon stocks to the Skagit River. Coho salmon were counted at the Baker River trap before tagging began in the lower river during two years of the study. In the other years of the study, coho salmon were counted at the trap so soon after tagging was initiated that we assumed some fish had migrated past the tagging site before tagging had begun and, therefore, were not subject to capture. Since these early-arriving fish were not subject to tagging, we excluded them from the number of fish examined for tags that was used for the population estimates (i.e., they were not considered in-sample). We examined the number of days between release and recapture for all coho salmon recovered at the Baker River trap during the five years of tagging. The minimum travel time (number of days between being tagged and released in the lower river and recovered at Baker River trap) observed during the study years was four days (Conrad et al. 1997). Therefore, all fish counted at the Baker River trap prior to four days after tagging had begun were excluded from the in-sample survey.

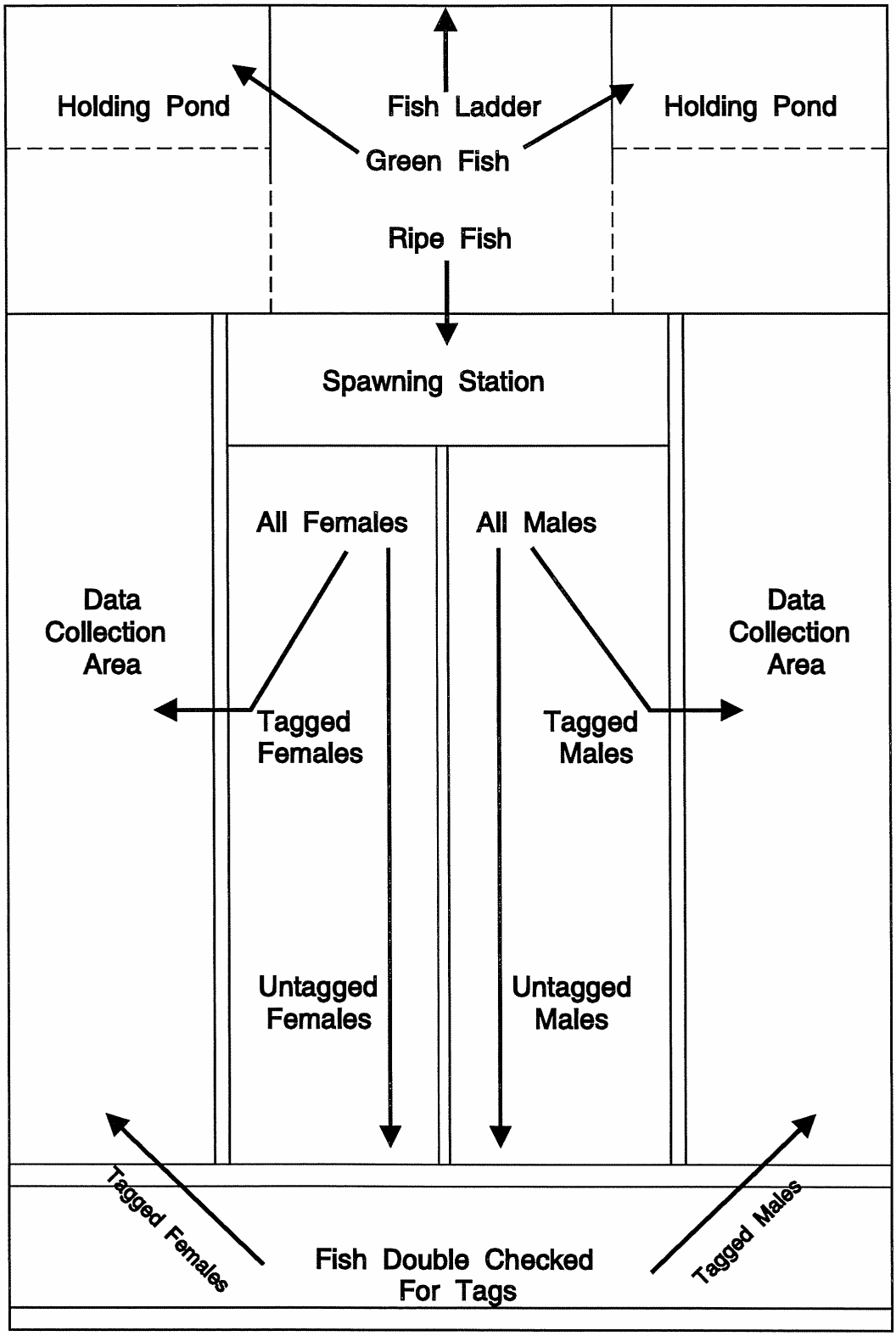

Figure 3. Schematic of the sampling procedure used to process coho salmon for tag examination at Marblemount Hatchery.

In-River Commercial and Test Fisheries:

Tag recovery samples from the commercial catch were collected in conjunction with routine commercial catch sampling activities. The Skagit River is divided into statistical areas for commercial catch regulation (Figure 4). In later years, to allow tag recovery samples from the catch to be analyzed by area of capture, all major salmon buyers were instructed to place catches from each statistical area into separate bins. In 1987, however, samples were not allocated to the sub-areas (78D-2, 78D-3, etc.) within Area 78D so we assumed that all samples were collected from the upstream areas (78D-3 or 78D-4) for the population analyses.

A test fishery was conducted each year by an SSC crew to provide an in-season assessment of the size of the coho salmon run. In 1987, test fisheries were conducted in: Area 2; Blakes; and Jetty in Skagit Bay (Figure 4). Drift and set gill nets used at the test fish sites had mesh sizes ranging from 5″ to 6″. Hayman (1996) describes the test fishing procedures in detail. All coho salmon caught during the test fishery were inspected for tags or marks.

Both WDFW and tribal commercial catch and hatchery samplers in areas outside of the Skagit River were notified to look for jaw tags from the Skagit River study. These recoveries allowed us to assess the degree of out-of-system straying for coho salmon tagged in the mainstem of the Skagit River.

Spawning Grounds:

Tag recovery surveys of the spawning grounds were conducted in conjunction with surveys to estimate the coho salmon escapement using redd counts (Conrad et al. 1993). For the redd-count method, the Skagit River system was stratified into the nine sub-basins listed by Johnson (1986): Carpenter; Nookachamps; Middle Skagit; Upper Skagit; Lower Sauk; Middle Sauk; Upper Sauk; Suiattle; and Cascade (Figure 1). Stream sections in each sub-basin were surveyed from one to 11 times during the spawning period for coho salmon. In 1987, about 20% of the total length of potential spawning habitat in the Skagit River was surveyed (Conrad et al. 1993). During spawning ground surveys, any coho salmon carcasses observed were sampled for jaw tags and opercula marks. Gill opercula of untagged carcasses were carefully inspected for marks or healed marks. A healed (regenerated) mark was evident as a perfectly round discoloration on the gill cover that was lighter in color than the surrounding opercular tissue. Occasionally a carcass could not be sampled because of a missing head due to advanced decomposition or removal by predators. Unsampled carcasses were tallied during each survey. The date, survey location, number of coho salmon carcasses sampled, number of tagged or marked fish recovered, and tag numbers of all coho salmon recovered with legible jaw tags were recorded during these surveys. The caudal fin of all sampled carcasses was removed to prevent the carcass from being sampled again during subsequent surveys.

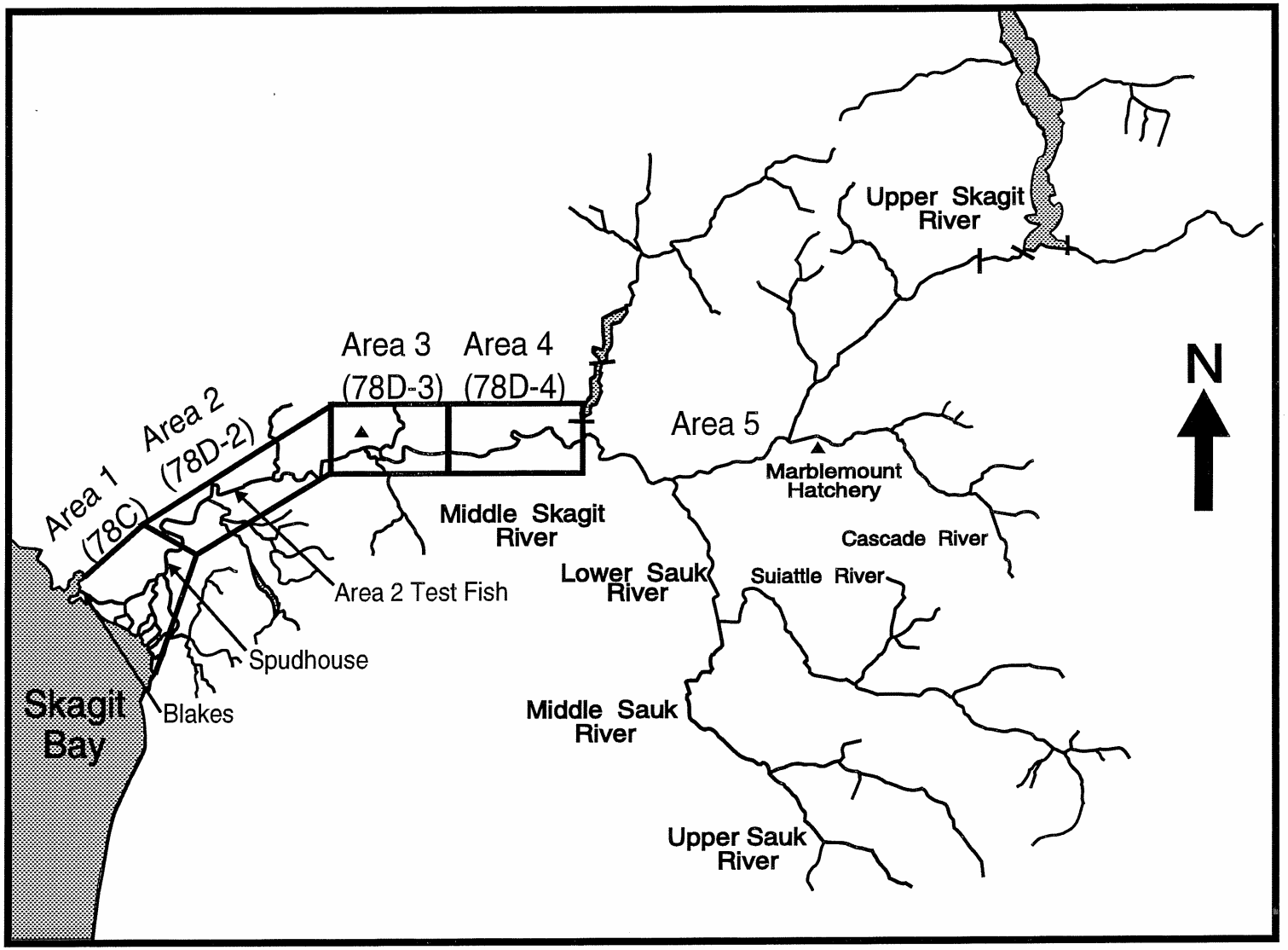

Figure 4. Commercial fishery areas of the Skagit River as designated by WDFW.

Tributary Traps:

SSC operated six fish traps in 1987. Two traps were on tributaries to Carpenter Creek (Fisher Creek and Carpenter Creek Slough), and there was one trap on Hansen Creek (a tributary to the Middle Skagit sub-basin) and one on Barnaby Slough (a tributary to the Upper Skagit sub-basin). All these traps were wooden weirs that blocked the entire creek and funneled fish into a live box. An additional weir trap was installed on Tank Creek, a tributary to the Middle Skagit. The trap on the East Fork of Nookachamps Creek was located about 1.5 miles from the mouth. It was a wire-mesh hoop trap that blocked only a portion of the creek but had visual lead nets attached that stretched from bank to bank. All traps were located in areas that had easy accessibility, a section of relatively straight stream channel with a low gradient, and a stable substrate.

All traps were checked and cleaned at least twice daily. A knotless-nylon dip net was used to move the trapped coho salmon into a 30-gallon plastic container filled with water. All coho salmon caught were examined for tags or marks and then released upstream. A Petersen disk tag and a unique operculum punch (i.e., a punch pattern different from that used in the main-river tagging) were placed on all coho salmon released above the traps. The trap crews also recovered tags at the weirs from spawned-out carcasses which had washed downstream from the spawning areas (called rack recoveries). The caudal fin was cut off all rack recoveries. The date, number of coho salmon sampled, number of tagged or marked fish recovered, and tag numbers of all coho salmon recovered with legible jaw tags were recorded.

Abundance Estimates

Two different mark-recapture models were used to estimate the number of coho salmon passing through the tagging area in the lower Skagit River, the Petersen estimation model and Darroch's stratified estimation model. When tagging and recovery occur over an extended time period, such as occurred in this study, it is not uncommon to observe temporal changes in: (1) the probability of capture of fish in the target population; and/or (2) the probability of finding a tagged fish during tag recovery surveys. When such changes occur the Petersen model is often not the appropriate estimation model. Seber (1982) describes a series of χ^2 tests to determine whether the data are consistent with a Petersen estimate. Specifically, the tests determine whether the data are consistent with the following four conditions: (1) there was uniform recovery of tags across the tag recovery strata; (2) there was uniform tagging across the tag release strata; (3) there was complete mixing of the population between tagging and recovery; and (4) the expected number of tags recovered in each stratum was proportional to the number of unmarked individuals present.

Eames et al. (1981, 1983) describe the exact form of these tests for a study similar to ours in both the study design and estimation procedures. They captured chum and coho salmon in marine areas immediately in front of the mouths of major river systems in Puget Sound and tagged the fish with jaw tags. Tags were recovered during surveys of spawning grounds throughout these river systems. We followed procedures similar to those described by Eames et al. (1981, 1983) to determine the appropriate estimation model.

Petersen Estimation Model:

The simplest and most commonly used model for estimating abundance from mark-recapture data is the Petersen model. Conrad et al. (1997) discuss the necessary assumptions for the Petersen model as implemented for this study.

Robson and Regier (1964) recommend that a Petersen estimate include a minimum of seven tag recaptures to ensure that the bias of the estimate is negligible. Therefore, we estimated abundance from the tagging data only when there were at least seven recaptures of tagged or marked coho salmon from a recovery area. Chapman's unbiased form of the Petersen estimate (Seber 1982) was used to estimate abundance. Conrad et al. (1997) describe the model and the procedures used to estimate 95% confidence intervals. For any Petersen-type estimator (including Darroch's stratified estimator), the abundance estimate depends upon ρ, the proportion of the population tagged. The proportion of tags in the second (recovery) sample provides an estimate of ρ. Generally, as $\hat{\rho}$ becomes smaller the estimated abundance becomes larger for a given number of tags released.

Darroch's Stratified Estimation Model:

Darroch (1961) developed a stratified population model for open populations that is not predicated on constant probabilities of capture or recovery. The necessary assumptions for this model are discussed in Seber (1982) and summarized by Conrad et al. (1997). Conrad et al. (1997) also describe the model and its application to the tag release-and-recovery data collected for this study.

Definition of Strata:

Two different tag recovery percentages were examined to help define tag release and tag recovery strata. To determine if the probability of finding a tagged fish in recovery samples was different among recovery locations or among different time periods at the same location, the percentages of tags in recovery samples (ρ as defined previously) were compared. The percentages of tags recovered from releases during specific time strata, π, were compared to determine if there were differences in the probability of recovering fish tagged during different segments of the release period. For these tests it was necessary to define temporal strata for both the tag release data and the tag recovery data from each recovery area.

Tag release strata were established by dividing the release data into four to six strata with about an equal number of days of tagging in each stratum. The percentages of tagged fish recovered from each release stratum (π) were tested to determine if they were equal. If a significant difference was found ($P \leq 0.10$) additional χ^2 tests were conducted to more precisely define the release strata by pooling adjacent strata which did not have significantly different π.

Three different criteria were used to establish tag recovery strata: (1) number of days of sampling; (2) number of tags recovered; and (3) number of fish examined for tags. Initially, two recovery strata were defined by dividing the data so there were approximately equal numbers of the criteria (days surveyed, number of tags, or number of fish examined) in each stratum. The percentages of tagged fish in each recovery stratum (ρ) were tested to determine if they were equal among recovery strata for each stratification criteria. If a significant difference was found ($P \leq 0.10$) additional χ^2 tests were conducted within the initial strata to more precisely define the recovery strata.

Testing ρ and π:

Tests were conducted to determine if there were significant differences in tag recovery percentages (either ρ or π) between different samples or groups of fish (e.g., between surveys conducted by SSC and WDFW, or between samples collected during different time periods, or between samples collected at different locations, or between male and female coho salmon). When the expected number of tag recoveries for each group in a comparison was five or greater, a standard χ^2 test (Conover 1980) was used to test for differences in tag recovery percentages (ρ or π). If the number of tag recoveries was insufficient for a χ^2 test (one or more cells with expected frequencies less than five) and there were only two release strata or recovery locations to compare, Fisher's exact test (Conover 1980) was used. Otherwise, an approximate randomization test (ART) was conducted (Noreen 1989). An approximate randomization test is a computer-intensive method of testing whether the data in a contingency table are similar. It is similar to Fisher's exact test but uses a computer to repeatedly resample the data and approximately estimate the probability of observing the configuration of the data in the table (under the null hypothesis that the samples are from the same population).

Selection of Estimation Models:

If we assume that coho salmon bound for each recovery area are randomly sampled as they migrate through the lower river tagging area, the recovery data (number of tagged or marked fish found and number of fish examined) from each recovery area can be used to estimate ρ, the percentage of the population that was tagged. If the hypothesis of equal $\hat{\rho}$ among recovery areas was not rejected ($P > 0.10$), the tag recovery data from the different areas were pooled. The pooled data were then used in the tests to determine if the tag release-and-recovery data were consistent with the Petersen model. We feel that the variation in $\hat{\rho}$ among the recovery areas generally reflects sampling variation in the recovery areas. The number of carcasses examined for tags was relatively small from some recovery areas. In some cases, all samples were collected from a relatively discrete area within the general recovery area which could influence the proportion of tagged carcasses present. Generally, the areas with greatly different recovery percentages (more than a 0.5% difference from the major recovery areas) had less than seven tag recoveries each. The different population estimates that were generated using the data from different recovery areas (or pooled recovery areas) were usually not significantly different from each other. Therefore, we selected the estimate with the smallest coefficient of variation as the "best" estimate of abundance for each year.

The model used to estimate abundance, simple Petersen or Darroch's stratified, was determined by the results of the tests for the consistency of the data. The four χ^2 tests used to determine consistency are described by Seber (1982) and by Eames et al. (1981, 1983).

Allocating Marked-Only Fish to Release Strata:

From 12% to 24% of the in-sample recoveries each year had a tag with an illegible number or had no tag and were identified as tagged fish by the opercula punches. The release stratum for these fish was unknown and had to be estimated for the stratified estimator. Marked fish with missing or illegible tags were allocated to release strata within a recovery area based on the proportional distribution of legible tags from each release stratum (Conrad et al. 1997). This assumes that tag loss or tag illegibility is a random process and that coho salmon tagged during each release stratum have equal rates of tag loss, therefore, fish with missing or illegible tags are assumed to have a similar distribution for stratum of release as fish with legible tags. If tag loss (or a tag becoming illegible) is a time dependent process, then fish tagged during the earlier release strata might be expected to have higher rates of tag loss and this assumption would not be true. Eames et al. (1981, 1983) used procedures similar to ours to allocate fish recovered with missing tags to release strata in their study. Errors in the assignment of marked-only fish to release strata affect only the Darroch estimate.

Additional Analyses

Several additional analyses of the data collected during tagging and tag recovery surveys were conducted. These included analyses to determine the timing of the migration of different spawning groups through the tagging area and analyses of sex and length composition data. These analyses were not required for the abundance estimates but were conducted to describe the characteristics of the annual return of coho salmon to the Skagit River during the study years.

Migratory Timing to Major Recovery Areas:

The timing of coho salmon migrating through the lower river tagging area was estimated from an analysis of the release dates of the tags recovered in each major recovery area (excluding commercial and test fisheries). Only areas with ten or more legible tag recoveries were included in the analyses. Ten, 10-day time periods were defined for the migratory timing calculations: (1) 1 September to 10 September; (2) 11 September to 20 September; (3) 21 September to 30 September; (4) 1 October to 10 October; (5) 11 October to 20 October; (6) 21 October to 30 October; (7) 31 October to 9 November; (8) 10 November to 19 November; (9) 20 November to 29 November; and (10) 30 November to 9 December.

Catch-per-unit effort (CPUE) by the beach seine used to capture coho salmon for tagging was used to describe the timing of the run through the tagging area in the lower river. CPUE was calculated for each 10-day period as the total number of coho salmon caught divided by the total number of beach seine sets (catch per set). The number of tags recovered in each major recovery area from each of the release periods was used to estimate the CPUE of coho salmon bound for these areas. The CPUE of coho salmon from recovery area *j* during release period *i* was estimated by:

$$\hat{\omega}_{ij} = \frac{r_{ij}}{f_i} \qquad [1]$$

where $\hat{\omega}_{ij}$ = the estimated CPUE of coho salmon from recovery area *j* during release period *i*,
r_{ij} = the number of tags recovered in area *j* that were released during period *i*, and
f_i = the number of beach seine sets made during period *i*.

For each area analyzed, the CPUE estimated for each 10-day period was summed across all ten time periods to estimate a season total CPUE of coho salmon bound for that recovery area. The estimated CPUE of coho salmon from recovery area *j* during time period *i* was converted to the percentage of this season total CPUE for recovery area *j* to describe migratory timing (Mundy 1982). These data were then graphed so that the migratory timing patterns for the major recovery areas could be compared.

Analyses of Sex and Length Composition Data:

Significant differences in the probability of recovering coho salmon tagged during different release periods (π) were found at some recovery locations in 1987. Temporal trends in the probability of recovery could be due to changing environmental conditions at the tagging site which influenced the probability of capture. For example, high and low water conditions may have influenced the effectiveness of the beach seine used to capture fish in the tagging area. Under low water conditions a higher proportion of the coho salmon present might have been caught than under high water conditions. Another possible explanation is that physical characteristics of the fish themselves (for example, sex or length) may influence both rate of capture for tagging and rate of recovery in tag recovery samples. For example, the beach seine may capture larger coho salmon at a higher rate than smaller coho salmon so that a higher proportion of the larger fish were tagged. As long as there is random mixing of coho salmon tagged during different time periods in the recovery areas, and the recovery process does not have the same selectivity as the capture process, this presents no problems for the abundance estimates.

Significant differences in the probability of finding a tag during surveys conducted at different times in a recovery area (ρ) were often found. Temporal trends in the physical characteristics of the population, combined with temporal trends in capture efficiency at the tagging site, could cause the changes observed. During spawning ground surveys, male fish may be more

likely to end up in locations that are sampled than female fish, or larger fish may have a higher probability of being seen and sampled during spawning ground surveys than smaller fish. The available data were examined to determine if these influences were present. The data used in these analyses were the length and sex composition data for all coho salmon tagged at the lower river tagging site and the tag recovery data used for the population estimates. Coho salmon recovered with a missing or illegible tag but having an operculum punch could not be used since their length and sex were not recorded at time of recovery.

Seber (1982) recommends testing the release (tagging) and recovery (escapement) samples for randomness with respect to length. The recovery sample was tested by comparing the length distributions of individuals that were tagged but not recovered to those individuals that were tagged and recovered. Both a Mann-Whitney U test and a Kolmogorov-Smirnov (K-S) test (Conover 1980) were used to compare the length distributions of coho salmon from these two groups. These same tests were also used to compare the length distributions of male and female coho salmon that were tagged in the lower Skagit River.

If there was a significant difference between the length distributions of male and female coho salmon subsequent analyses were conducted for each sex separately. If there was a significant difference between the length distributions of coho salmon which were tagged but not recovered and those that were tagged and recovered, K-S tests were performed sequentially on the length distributions to determine length categories with no significant difference between these two groups. Testing began between 65 and 70 cm (above which the length distributions of the two groups were not significantly different) and length was sequentially decreased by one cm intervals until a significant difference ($P \leq 0.05$) between the groups was found. A K-S test was then performed on those fish that were at the length of the significant difference or smaller. If there was a significant difference between the fish which were tagged but not recovered and those that were tagged and recovered the process was repeated for the fish in this smaller length range.

RESULTS

The results of the tagging conducted in 1987 are summarized in the following five sections. The summary consists of: (1) tag releases by day; (2) tag recoveries by location; (3) abundance estimates produced using the tag release-and-recovery data; (4) additional analyses which include migratory timing information from the release-and-recovery data and sex-length composition data; and (5) a discussion of the "best" estimate of the number of coho salmon migrating through the tagging area in the lower Skagit River.

There are two different tag recovery percentages presented in the results: the percentage of tags recovered from the tag releases during a specific time stratum (π) and the percentage of tagged fish in samples collected during tag recovery surveys (ρ). The recovery data from each major area were tested to determine if there were significant temporal differences in both of these percentages. The results of these tests determined which data were pooled and which model was used to estimate the abundance of coho salmon using the recovery data for a specific area or group of areas pooled.

Tag Releases

The beach seining began on 2 September but no coho salmon were caught that day. Tagging began on 3 September and continued through 20 November. Beach seining was conducted on 3 December but no coho salmon were caught. A total of 5,425 coho salmon were tagged during 38 days of tagging (Table 1). About 25% of the tagged fish were eventually recovered during surveys conducted to estimate the percentage of tagged fish in the escapement.

The percentage of each day's release of tags that was recovered ranged from 0% to 35% (Figure 5). Generally, coho salmon tagged and released during October were recovered at a higher rate than those tagged and released in September and November. Four temporal release strata were defined to determine if there were significant differences in π among the release strata using the recoveries at each major area. The four release strata were:

1. 2 September through 18 September;
2. 21 September through 9 October;
3. 12 October through 30 October; and
4. 2 November through 3 December.

Significant differences in π among the release strata were found for the recoveries at Marblemount Hatchery, Baker River trap, Middle Skagit spawning grounds, the commercial fishery, and for all recovery data combined (Table 2). There were no significant temporal differences in π among release strata at the other major recovery areas (Upper Skagit, Lower Sauk, Middle Sauk, Upper Sauk, Suiattle, and combined upriver spawning grounds). These tests were conducted only for recovery areas with seven or more legible tag recoveries.

Table 1. Number of coho salmon tagged each day and number of in-sample tag recoveries from each day's release for the Skagit River, 1987.

	Number	Tag Recoveries by Area[a]											Recoveries	
Date	Tagged	MMH	BAK	MSK	USK	LSA	MSA	USA	SUI	OTH	CFS	TFS	Total	% (π)
02-Sep	0													
03-Sep	3	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
04-Sep	1	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
08-Sep	22	0	0	0	0	0	0	0	1	0	0	0	1	4.5%
10-Sep	82	2	2	1	1	1	0	0	1	0	0	1	9	11.0%
11-Sep	59	3	2	0	0	0	0	0	0	0	0	0	5	8.5%
14-Sep	24	1	1	0	1	0	0	0	0	0	0	0	3	12.5%
15-Sep	85	9	3	0	0	0	0	0	1	1	0	0	14	16.5%
17-Sep	180	19	3	1	0	0	1	1	2	0	0	0	27	15.0%
18-Sep	149	13	8	0	0	0	0	0	2	0	0	0	23	15.4%
21-Sep	122	11	2	0	1	0	0	0	1	0	0	0	15	12.3%
22-Sep	171	22	0	0	3	1	1	0	2	0	0	1	30	17.5%
25-Sep	255	48	6	0	2	0	1	0	2	1	0	0	60	23.5%
29-Sep	139	21	2	0	2	1	1	2	1	0	0	0	30	21.6%
01-Oct	210	40	7	1	3	0	1	0	2	0	0	0	54	25.7%
02-Oct	220	37	8	0	5	0	1	1	0	0	0	0	52	23.6%
05-Oct	278	50	5	0	4	0	3	3	0	0	0	0	65	23.4%
06-Oct	119	17	0	0	2	0	1	1	0	0	1	0	22	18.5%
08-Oct	162	30	2	0	5	2	2	1	0	1	0	0	43	26.5%
09-Oct	573	113	10	2	3	1	3	0	2	1	0	0	135	23.6%
12-Oct	165	24	4	1	2	0	1	0	0	0	1	1	34	20.6%
16-Oct	155	27	3	1	3	1	1	1	1	0	0	0	38	24.5%
19-Oct	150	31	3	0	2	0	1	0	1	0	0	0	38	25.3%
20-Oct	121	21	3	1	1	0	0	1	1	1	0	0	29	24.0%
23-Oct	205	50	8	0	3	0	0	0	3	1	1	0	66	32.2%
26-Oct	57	15	1	0	0	0	0	0	0	0	0	0	16	28.1%
27-Oct	23	6	1	0	0	1	0	0	0	0	0	0	8	34.8%
29-Oct	39	9	1	1	1	0	0	0	0	0	0	0	12	30.8%
30-Oct	88	16	2	0	2	1	1	0	0	0	0	0	22	25.0%
02-Nov	571	117	8	2	6	1	2	0	3	0	2	0	141	24.7%
03-Nov	193	42	2	1	3	1	0	0	2	0	3	0	54	28.0%
04-Nov	84	10	1	3	1	1	0	0	0	0	1	0	17	20.2%
06-Nov	60	4	0	0	0	0	0	0	1	0	1	0	6	10.0%
10-Nov	166	18	1	4	4	0	1	0	0	1	2	0	31	18.7%
12-Nov	232	28	0	10	1	1	1	0	0	0	6	0	47	20.3%
13-Nov	243	32	2	4	1	2	1	0	0	1	6	0	49	20.2%
18-Nov	8	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
19-Nov	2	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
20-Nov	9	0	0	0	0	0	0	0	0	0	0	0	0	0.0%
03-Dec	0													
UNKNOWN[b]		76	10	18	18	5	18	7	9	9	0	0	170	
TOTALS	5,425	962	111	51	80	20	42	18	38	17	24	3	1,366	
% Recovered		17.7%	2.0%	0.9%	1.5%	0.4%	0.8%	0.3%	0.7%	0.3%	0.4%	0.1%	25.2%	

[a] Locations are: MMH - Marblemount Hatchery; BAK - Baker River trap; MSK - Middle Skagit sub-basin; USK - Upper Skagit sub-basin; LSA - Lower Sauk sub-basin; MSA - Middle Sauk sub-basin; USA - Upper Sauk sub-basin; SUI - Suiattle sub-basin; OTH - Cascade, Nookachamps, and Carpenter sub-basins; CFS - Commercial fishery; and TFS - Test fishery.

[b] Fish recovered with no tag but having the secondary mark (an operculum punch) or an illegible tag.

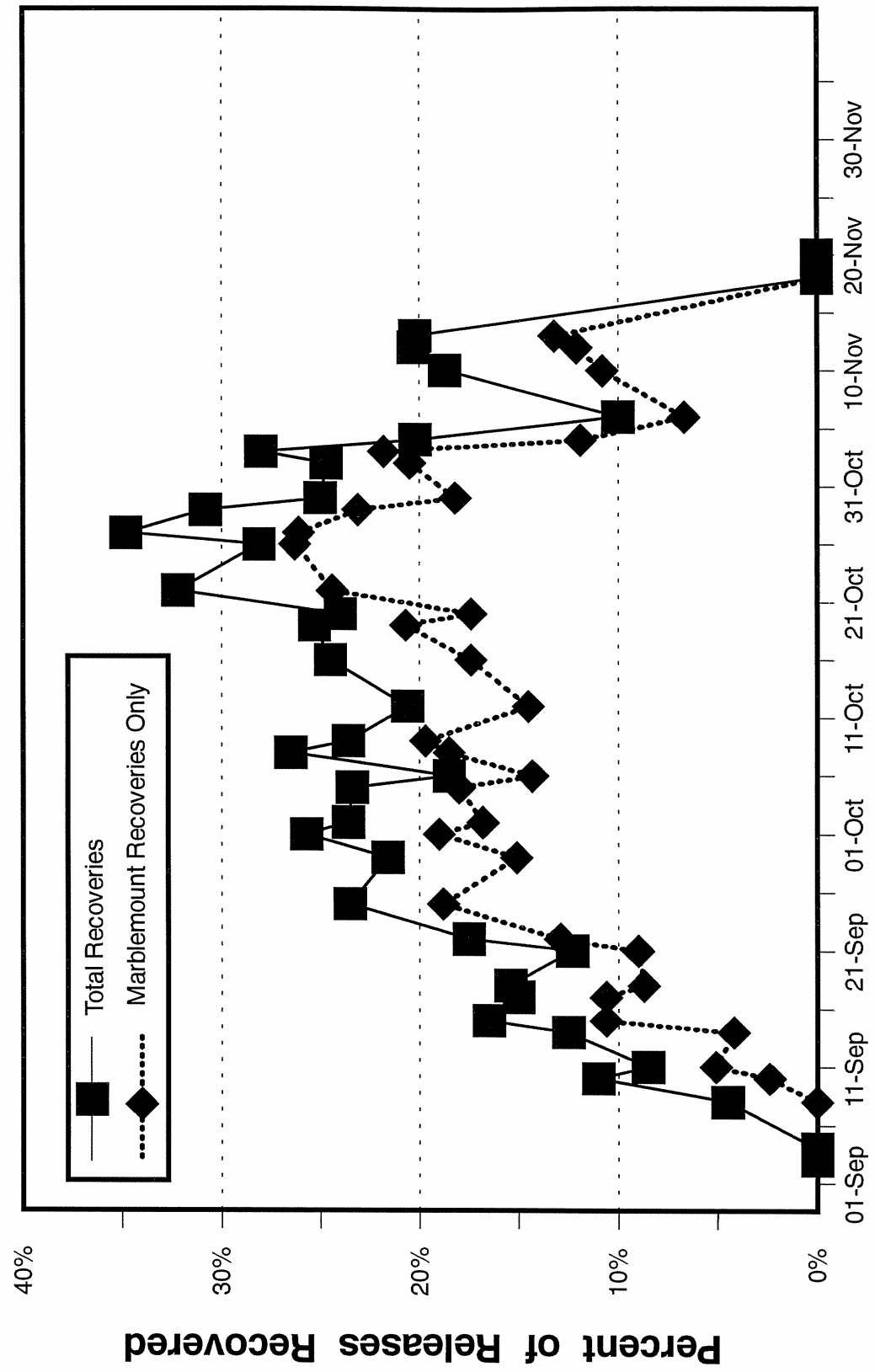

Figure 5. Percent of tags recovered during in-sample surveys from each day of release for coho salmon tagged in the Skagit River, 1987.

Table 2. Summary of the number of tag recoveries (#) from each release stratum in each major recovery area and the results of testing recovery percentages (π) for equality among release strata, 1987.

		RECOVERY AREA											
	Number	Marblemount		Baker R.		Mid. Skagit		Up. Skagit		Low. Sauk		Mid. Sauk	
Release Strata	Tagged	#	π	#	π	#	π	#	π	#	π	#	π
2-Sep thru 18-Sep	605	47	7.8%	19	3.1%	2	0.3%	2	0.3%	1	0.2%	1	0.2%
21-Sep thru 9-Oct	2,249	389	17.3%	42	1.9%	3	0.1%	30	1.3%	5	0.2%	14	0.6%
12-Oct thru 30-Oct	1,003	199	19.8%	26	2.6%	4	0.4%	14	1.4%	3	0.3%	4	0.4%
2-Nov thru 3-Dec	1,568	251	16.0%	14	0.9%	24	1.5%	16	1.0%	6	0.4%	5	0.3%
TOTALS	5,425	886	16.3%	101	1.9%	33	0.6%	62	1.1%	15	0.3%	24	0.4%
TEST RESULTS[b]													
Test Used:			χ^2		χ^2		χ^2		χ^2		ART		ART
Significance (P):			< 0.01 ***		< 0.01 ***		< 0.01 ***		0.17 NS		0.80 NS		0.34 NS

- continued -

Table 2. Summary of the number of tag recoveries (#) from each release stratum in each major recovery area and the results of testing recovery percentages (π) for equality among release strata, 1987 (continued).

		RECOVERY AREA									
	Number	Up. Sauk		Suiattle		Spawn. Gr.[a]		Comm. Fishery		Total	
Release Strata	Tagged	#	π	#	π	#	π	#	π	#	π
2-Sep thru 18-Sep	605	1	0.2%	7	1.2%	15	2.5%	0	0.0%	82	13.6%
21-Sep thru 9-Oct	2,249	8	0.4%	10	0.4%	72	3.2%	1	0.1%	506	22.5%
12-Oct thru 30-Oct	1,003	2	0.2%	6	0.6%	34	3.4%	2	0.2%	263	26.2%
2-Nov thru 3-Dec	1,568	0	0.0%	6	0.4%	58	3.7%	21	1.3%	345	22.0%
TOTALS	5,425	11	0.2%	29	0.5%	179	3.3%	24	0.4%	1,196	22.0%
TEST RESULTS[b]											
Test Used:			ART		χ^2		χ^2		χ^2		χ^2
Significance (P):			0.42 NS		0.14 NS		0.54 NS		< 0.01 ***		< 0.01 ***

[a] Total for all spawning ground samples from the Middle Skagit sub-basin and above. The total does not include recoveries from Marblemount Hatchery, Baker River trap, or the Nookachamps and Carpenter sub-basins.

[b] Results of the tests to determine if the recovery percentages (π) were different among release strata. Test used: χ^2 = chi-square test, ART = approximate randomization test. NS = Not Significant, * = Significant, $0.05 < P \leq 0.10$, ** = Significant, $0.01 < P \leq 0.05$, *** = Significant, $P \leq 0.01$.

Tag Recoveries

Samples to estimate ρ were collected at 13 areas in the Skagit River drainage. A total of 45,307 coho salmon were examined of which 45,286 fish were considered in-sample and 21 were not considered part of the population subject to tagging. Sample surveys were conducted at: Marblemount Hatchery; Baker River trap; spawning grounds in the Middle Skagit, Upper Skagit, Lower Sauk, Middle Sauk, Upper Sauk, Suiattle, Cascade, Nookachamps, and Carpenter sub-basins; and in commercial and test fisheries. Of the 1,366 in-sample recoveries, 170 fish (12%) had a tag with an illegible number or had a missing tag and were identified as tagged by the opercula punches. Most of the in-sample recoveries were at Marblemount Hatchery (962 recoveries or 70% of all in-sample recoveries). The areas with the next largest number of tag recoveries were Baker River (111 or 8%) and Upper Skagit sub-basin spawning grounds (80 or 6%). Combined, these three areas account for 84% of all in-sample recoveries.

The percentage of tagged fish in the escapement samples (ρ) from the eleven recovery areas having seven or more tag recoveries ranged from 0.7% for Nookachamps sub-basin samples to 4.1% for Upper Skagit sub-basin samples (Table 3). There was a significant difference (χ^2, $P < 0.01$) in ρ among these eleven areas.

The average number of days between release and recovery for in-sample tag recoveries was about 53 days (Table 4). Tagged coho salmon recovered in the test fishery had the shortest average time between release and recovery, 13 days, and tag recoveries in the Suiattle sub-basin had the longest average time between release and recovery, 81 days. For the upstream recovery areas, tag recoveries from the Upper Sauk sub-basin had the earliest average day of release (4 October) and recoveries from the Middle Skagit sub-basin had the latest average day of release (31 October).

Marblemount Hatchery:

Escapement samples were collected at Marblemount Hatchery from 27 October through 15 January. A total of 29,277 coho salmon were examined and 962 tagged fish (3.3%) were found (Appendix Table A-1). The Marblemount Hatchery sample is considered a census because all returning fish are sampled so the data were not examined for temporal differences in ρ.

Baker River Trap:

Escapement samples were collected at Baker River trap from 11 September through 15 January. A total of 4,097 coho salmon were examined for tags. Based upon a four-day minimum travel time from the tagging area to Baker River dam determined from all five years of tagging data (Conrad et al. 1997), samples collected on 11 September were not considered in-sample since substantial numbers of fish were not tagged until 8 September. A total of 4,076 coho salmon were examined for tags from 18 September through 15 January and 111 tagged fish (2.7%) were found (Appendix Table A-2). The Baker River trap sample is considered a census because all returning fish are sampled so the data were not examined for temporal differences in ρ.

Table 3. Summary of the percentage of tagged or marked coho salmon found in each recovery area during in-sample surveys of the Skagit River, 1987.

Recovery Area	Time Period	Fish Examined	Tags Found[a]	% Tagged (ρ)
Marblemount Hatchery	1. 27-Oct - 15-Jan	29,277	962	3.3%
Baker River Trap	X.[b] 11-Sep	21	0	0.0%
	1. 18-Sep - 15-Jan	4,076	111	2.7%
Upper Skagit Sub-basin	1. 16-Nov - 08-Dec	141	15	10.6%
	2. 09-Dec - 09-Feb	1,834	65	3.5%
	Total	1,975	80	4.1%
Middle Skagit Sub-basin	1. 16-Nov - 10-Feb	1,497	51	3.4%
Middle Sauk Sub-basin	1. 18-Nov - 18-Dec	449	16	3.6%
	2. 22-Dec - 10-Feb	1,447	26	1.8%
	Total	1,896	42	2.2%
Suiattle Sub-basin	1. 24-Nov - 10-Feb	1,051	38	3.6%
Commercial Fishery	1. 09-Sep - 20-Jan	754	24	3.2%
Lower Sauk Sub-basin	1. 30-Nov - 24-Dec	188	13	6.9%
	2. 29-Dec - 08-Feb	585	7	1.2%
	Total	773	20	2.6%
Upper Sauk Sub-basin	1. 02-Dec - 02-Feb	522	18	3.4%
Cascade Sub-basin	1. 19-Nov - 25-Jan	597	9	1.5%
IN-SAMPLE TOTAL FOR UPSTREAM AREAS		42,418	1,355	3.2%
Carpenter Sub-basin	1. 05-Nov - 02-Feb	349	0	0.0%
Nookachamps Sub-basin	1. 03-Nov - 03-Feb	1,159	8	0.7%
Test Fishery (downstream)	1. 17-Sep - 05-Nov	1,360	3	0.2%
IN-SAMPLE TOTAL FOR DOWNSTREAM AREAS		2,868	11	0.4%
TOTAL CONSIDERED IN POPULATION BEFORE TAGGING		21	0	0.0%
IN-SAMPLE TOTAL FOR ALL AREAS		45,286	1,366	3.0%
GRAND TOTAL FOR ALL SAMPLES		45,307	1,366	3.0%

[a]Includes fish recovered with no tag but having the secondary mark (an operculum punch) or having an illegible tag.

[b] X indicates that these fish were considered to be in the population before tagging began and not subject to tagging (i.e., they were not considered in-sample fish for the abundance estimates).

Table 4. Average day of release (DOR) and average number of days between release and recovery (DBET) for coho salmon tagged and recovered in the Skagit River, 1987.

Recovery Area	Sample Size[a]	Average DOR	Stand. Error	Range	Average DBET	Stand. Error	Range
Marblemount Hatchery:							
Pond Mortalities	83	13-Oct	1.6	17-Sep - 13-Nov	55.5	2.0	24 - 120
Surplused	518	14-Oct	0.7	10-Sep - 13-Nov	55.7	0.8	15 - 103
Spawned	285	18-Oct	1.0	11-Sep - 13-Nov	47.1	1.2	10 - 108
Baker River Trap	101	8-Oct	1.7	10-Sep - 13-Nov	28.5	1.6	4 - 64
Upper Skagit Sub-basin	62	14-Oct	2.1	10-Sep - 13-Nov	73.3	2.8	28 - 120
Middle Skagit Sub-basin	33	31-Oct	3.0	10-Sep - 13-Nov	54.5	4.2	11 - 120
Middle Sauk Sub-basin	24	12-Oct	3.3	17-Sep - 13-Nov	74.1	3.7	43 - 105
Suiattle Sub-basin	29	7-Oct	3.6	8-Sep - 6-Nov	80.7	4.0	42 - 118
Commercial Fishery	24	5-Nov	2.1	6-Oct - 13-Nov	23.8	3.5	4 - 48
Lower Sauk Sub-basin	15	20-Oct	5.2	10-Sep - 13-Nov	67.1	6.0	39 - 103
Upper Sauk Sub-basin	11	4-Oct	2.6	17-Sep - 20-Oct	71.9	4.7	55 - 105
Cascade Sub-basin	5	11-Oct	10.4	15-Sep - 13-Nov	66.6	9.2	39 - 89
Nookachamps Sub-basin	3	23-Oct	9.4	9-Oct - 10-Nov	73.3	9.4	59 - 91
Test Fishery	3	24-Sep	9.3	10-Sep - 12-Oct	12.7	2.9	8 - 18
All Recoveries	1,196	15-Oct	0.5	8-Sep - 13-Nov	52.8	0.6	4 - 120

[a] Includes tag recoveries with legible numbers only.

Commercial and Test Fishery Samples:

An in-river commercial fishery was conducted in the upper river on 13 days between 9 September and 20 January. A total of 754 coho salmon were examined for tags and 24 tagged fish (3.2%) were found. The hypothesis of constant ρ for temporal strata in the fishery samples could not be rejected (Appendix Table A-3).

Test fisheries were conducted on 14 days between 17 September and 5 November. All test fisheries were conducted below the tagging area. A total of 1,360 coho salmon were examined for tags and three tagged fish (0.2%) were found (Appendix Table A-4).

Middle Skagit Sub-basin:

Tag recovery samples were collected during surveys of Middle Skagit sub-basin spawning grounds conducted from 16 November through 10 February and at the Hansen Creek trap operated from 23 November through 26 January. No fish were caught at the trap on Tank Creek because there was no water in the creek during the study. Surveys were conducted by SSC and WDFW crews. There was not a significant difference in ρ among samples collected by the two agencies or at the trap (χ^2, $P = 0.19$) so all samples were combined. A total of 1,497 coho salmon were examined for tags and 51 tagged fish (3.4%) were found (Appendix Table A-5). The hypothesis of constant ρ for temporal strata in the recovery samples could not be rejected.

Upper Skagit Sub-basin:

Tag recovery samples were collected during surveys of Upper Skagit sub-basin spawning grounds conducted from 16 November through 9 February and at the Barnaby Creek trap operated from 4 December through 29 January. Surveys were conducted by SSC and WDFW crews. There was not a significant difference in ρ among samples collected by the two agencies or at the trap (ART, $P = 0.69$) so the samples were combined. A total of 1,975 coho salmon were examined for tags and 80 tagged fish (4.1%) were found (Appendix Table A-6). There was a significant difference (χ^2, $P < 0.01$) in ρ between samples collected from 16 November through 8 December and samples collected after 8 December.

Lower Sauk Sub-basin:

Tag recovery samples were collected during surveys of Lower Sauk sub-basin spawning grounds conducted from 30 November through 8 February. Surveys were conducted by SSC and WDFW crews. There was not a significant difference in ρ between samples collected by the two agencies (χ^2, $P = 0.88$) so the samples were combined. A total of 773 coho salmon were examined for tags and 20 tagged fish (2.6%) were found (Appendix Table A-7). There was a significant difference (χ^2, $P < 0.01$) in ρ between samples collected from 30 November through 24 December and samples collected after 24 December.

Middle Sauk Sub-basin:

Tag recovery samples were collected during surveys of Middle Sauk sub-basin spawning grounds conducted from 18 November through 10 February. Surveys were conducted by SSC and WDFW crews. There was not a significant difference in ρ between samples collected by the two agencies (χ^2, $P = 0.77$) so the samples were combined. A total of 1,896 coho salmon were examined for tags and 42 tagged fish (2.2%) were found (Appendix Table A-8). There was a significant difference (χ^2, $P = 0.02$) in ρ between samples collected from 18 November through 18 December and samples collected after 18 December.

Upper Sauk Sub-basin:

Tag recovery samples were collected during surveys of Upper Sauk sub-basin spawning grounds conducted from 2 December through 2 February. Surveys were conducted by SSC crews. A total of 522 coho salmon were examined for tags and 18 tagged fish (3.4%) were found (Appendix Table A-9). The hypothesis of constant ρ for temporal strata in the recovery samples could not be rejected.

Suiattle Sub-basin:

Tag recovery samples were collected during surveys of Suiattle sub-basin spawning grounds conducted from 24 November through 10 February. Surveys were conducted by SSC crews. A total of 1,051 coho salmon were examined for tags and 38 tagged fish (3.6%) were found (Appendix Table A-10). The hypothesis of constant ρ for temporal strata in the recovery samples could not be rejected.

Other Spawning Ground Surveys:

Spawning ground surveys were conducted in three other areas: Nookachamps sub-basin, Carpenter sub-basin, and Cascade sub-basin. Tag recovery samples were collected during surveys of Nookachamps sub-basin spawning grounds by SSC and WDFW crews and at the East Fork trap. A total of 1,159 coho salmon were examined for tags and eight tagged fish (0.7%) were found (Appendix Table A-11). Spawning ground surveys of the Carpenter sub-basin were conducted by SSC crews and traps were operated by SSC on Fisher Creek and Carpenter Creek Slough. A total of 349 coho salmon were examined for tags but no tagged fish (0.0%) were found in these samples (Appendix Table A-12). SSC crews surveyed Cascade sub-basin spawning grounds and examined 597 coho salmon (Appendix Table A-13). Nine tags were recovered during surveys of the Cascade sub-basin (1.5%).

Out-of-System Recoveries:

There were four recoveries of jaw tags outside of the Skagit River system from the tagging conducted in the Skagit River during 1987. Three of the four recoveries were from marine areas both north and south of the mouth of the Skagit River. There were two tags recovered from commercial catches: one from WDFW statistical Area 8A or 10 (the exact area could not be determined) and the other from Similk Bay. These were voluntary recoveries and not recovered during commercial catch sampling. There was also a tagged coho salmon caught by a sport angler near Oak Harbor and voluntarily reported. There was one tag recovered during sampling at the Lummi Ponds fish hatchery in Lummi Bay. A total of 1,820 coho salmon were inspected at the hatchery rack from a return of 4,001 adult coho salmon.

Abundance Estimates

Estimates of coho salmon abundance from the tag recovery data for each major recovery area having seven or more tag recoveries are summarized in Table 5. The details of the abundance estimate for each location are in Appendix B. Even though there were eight tags recovered in the Nookachamps sub-basin, these data were not used to generate an abundance estimate. The Nookachamps sub-basin is substantially below the tagging area and we do not feel that all coho salmon from this area passed through the tagging area. The samples from Marblemount Hatchery and Baker River trap were both censuses so they were compared to determine if it was appropriate to pool them. The two samples were not significantly different (χ^2, $P = 0.11$) so an estimate was generated for the pooled data.

The four samples from sub-basins above the tagging area which had no significant (all $P > 0.05$) temporal differences in ρ (Middle Skagit, Suiattle, Upper Sauk, and Cascade) were compared, also. There was a significant difference in ρ among these areas when the Cascade sub-basin sample was included (χ^2, $P = 0.09$), but there was not a significant difference in ρ among the remaining three areas when the Cascade sample was excluded (χ^2, $P = 0.96$). Therefore, samples from these three areas (Middle Skagit, Suiattle, and Upper Sauk sub-basins) were pooled for an estimate. Finally, ρ for Marblemount Hatchery, Baker River trap, the commercial fishery, and the Middle Skagit, Suiattle, and Upper Sauk sub-basins were compared. The differences among ρ were not significant (χ^2, $P = 0.55$), therefore, samples from these six areas were pooled for an estimate.

Estimates of the number of coho salmon migrating through the lower Skagit River tagging area ranged from 142,836 coho salmon using Lower Sauk sub-basin recovery data to 324,474 coho salmon using Cascade sub-basin spawning ground recovery data. Pooled Marblemount-Baker-commercial fishery-Middle Skagit-Suiattle-Upper Sauk data provided the most precise estimate (CV = 2.5%). The estimate with the largest CV was from Lower Sauk sub-basin recovery data (CV = 206.7%). The 95% confidence intervals for the abundance estimates overlapped for each recovery area.

Table 5. Summary of estimates of the number of coho salmon in the Skagit River escapement using data from each major recovery area, 1987.

Recovery Area	Estimation Method	Estimated Abundance	Stand. Error	CV[a]	95% Confidence Interval
Marblemount	Petersen	164,965	4,739	2.9%	155,441 - 176,042
Baker River	Petersen	197,515	18,134	9.2%	168,321 - 243,982
Marblemount - Baker pooled	Petersen	168,508	4,528	2.7%	159,255 - 179,177
Upper Skagit	Darroch	148,527	97,000	65.3%	0 - 338,647
Middle Skagit	Petersen	156,310	20,994	13.4%	125,402 - 218,086
Middle Sauk	Darroch	232,531	40,332	17.3%	153,480 - 311,582
Suiattle	Petersen	146,362	22,627	15.5%	105,082 - 205,260
Commercial Fishery	Petersen	163,864	31,527	19.2%	107,660 - 253,608
Lower Sauk	Darroch	142,836	295,256	206.7%	0 - 721,537
Upper Sauk	Petersen	149,357	32,728	21.9%	91,554 - 249,203
M. Skagit - Suiattle - U. Sauk pooled	Petersen	154,288	14,371	9.3%	131,221 - 191,261
Cascade	Petersen	324,474	96,922	29.9%	160,317 - 702,803
Marblemount - Baker - M. Skagit - Suiattle - Commercial Fishery- U. Sauk pooled	Petersen	167,408	4,182	2.5%	158,694 - 177,368

[a] CV = coefficient of variation.

Additional Analyses

The release data were divided into ten, 10-day time periods for the migratory timing analysis and to describe temporal patterns in the length and sex composition of tagged coho salmon. Coho salmon were tagged and released during nine of these periods.

Timing of Migrations to Major Recovery Areas:

The CPUE of coho salmon by the beach seine in the lower river tagging area is shown by day and for each 10-day period in Figure 6. CPUE peaked during the 1 October through 10 October time period and during the 31 October through 9 November period. Eight areas had ten or more recoveries of legible tags which could be used for the migratory timing calculations (Appendix Table A-14). The trends in CPUE of Marblemount Hatchery fish and fish bound for spawning grounds in the Upper Skagit sub-basin were very similar to the trend for total CPUE by 10-day period (Figure 7). The CPUE of fish bound for Baker River, Upper Skagit sub-basin, Middle Sauk sub-basin, and Upper Sauk sub-basin spawning grounds all peaked during the 1 October through 10 October time period. Coho salmon bound for Middle Skagit sub-basin spawning grounds had the latest timing with 48% of the total CPUE of this group occurring in the 10 November to 19 November period.

Length and Sex Composition Analyses:

The sex and length data for the 5,425 coho salmon tagged and released in the lower Skagit River and the 1,196 in-sample recoveries with legible tags were analyzed. Both the K-S and M-W tests which compared the lengths of coho salmon tagged but not recovered to the lengths of those tagged and recovered were significant ($P \leq 0.02$) indicating that the recovery samples were not random with respect to length of fish. There was also a significant difference between male and female length distributions (K-S test, $P < 0.01$), therefore, all subsequent analyses of length were conducted for each sex separately. It is evident from Figure 8 that male coho salmon had a higher proportion of smaller sizes (fish less than 50 cm) than female coho salmon. Coho salmon less than 50 cm in length composed about 41% of the males that were tagged but only 14% of the female coho salmon that were tagged.

Males Tagged male coho salmon averaged 52.2 cm in fork length (SE = 0.15). The mean length of male coho salmon that were tagged but not recovered was 52.1 cm (SE = 0.18) compared to a mean length of 52.3 cm (SE = 0.26) for male coho salmon that were tagged and recovered. The length distribution of male coho salmon that were tagged but not recovered was significantly different (K-S test, $P < 0.01$) from the distribution of those that were tagged and recovered (Figure 9). Three length categories were defined from the sequential K-S tests for male coho salmon: (1) fish with lengths less than 48 cm; (2) fish with lengths from 48 cm through 57 cm; and (3) fish with lengths greater than 57 cm. The percentages of tagged coho salmon in each length category that were recovered were 17.6%, 29.5%, and 18.7%, respectively (Appendix Table A-15).

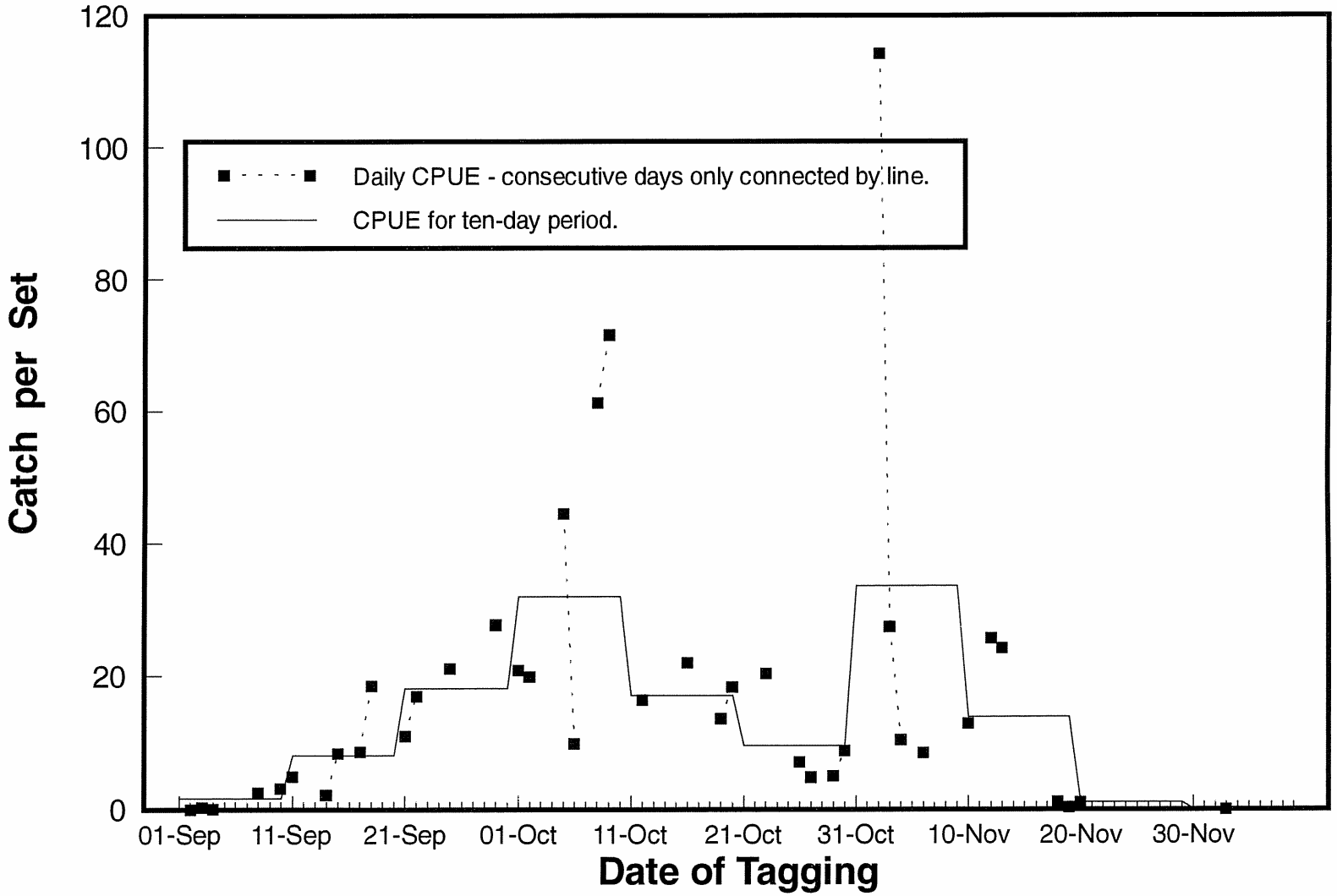

Figure 6. Catch-per-unit effort of coho salmon by the beach seine in the lower Skagit River tagging area by day and for each ten-day period, 1987.

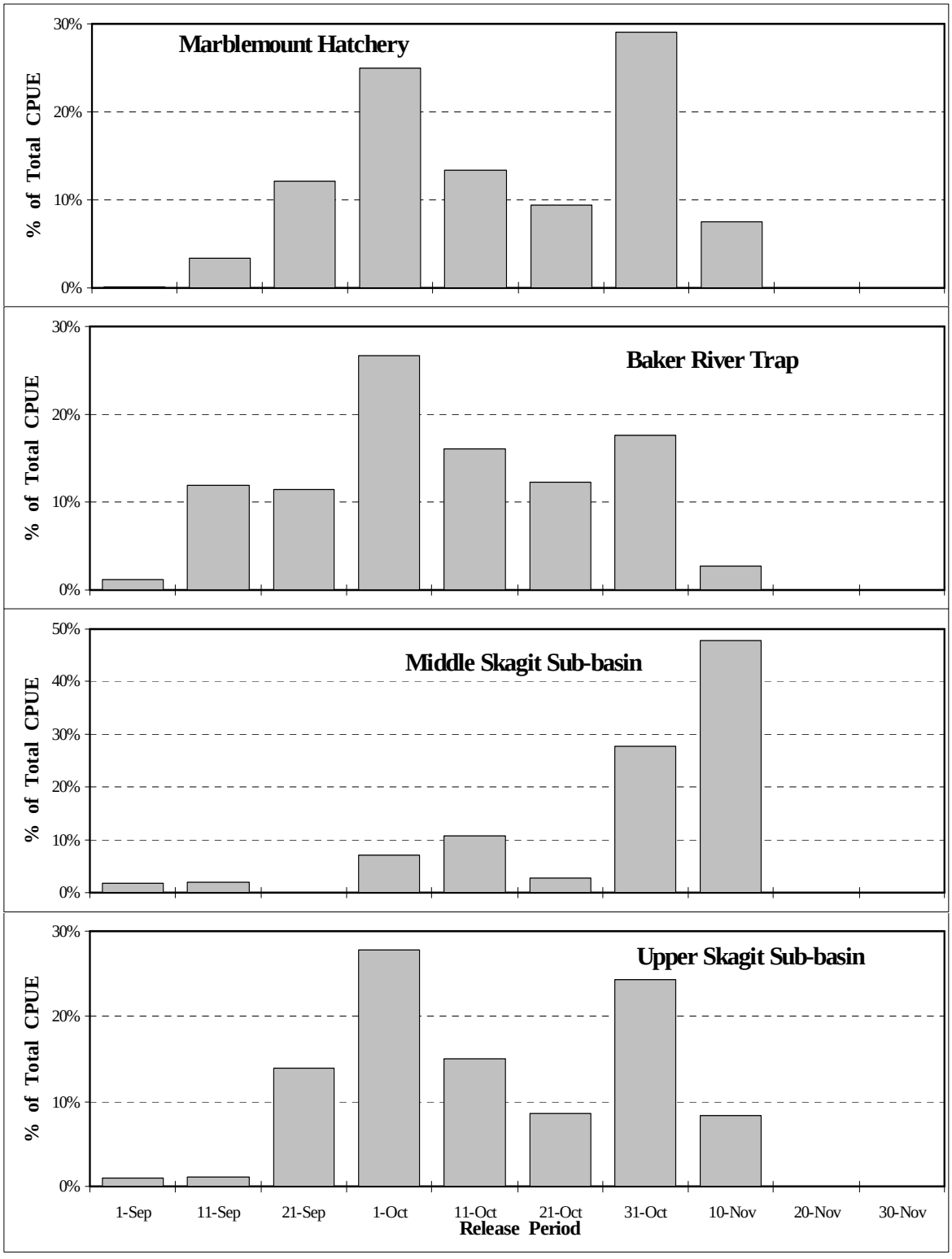

Figure 7. Beach seine catch-per-unit effort (CPUE) of coho salmon bound for major Skagit River tag recovery areas in 1987. CPUE is for ten-day periods (starting date of period shown) and is expressed as a percentage of the total CPUE for tagged fish recovered from the area.

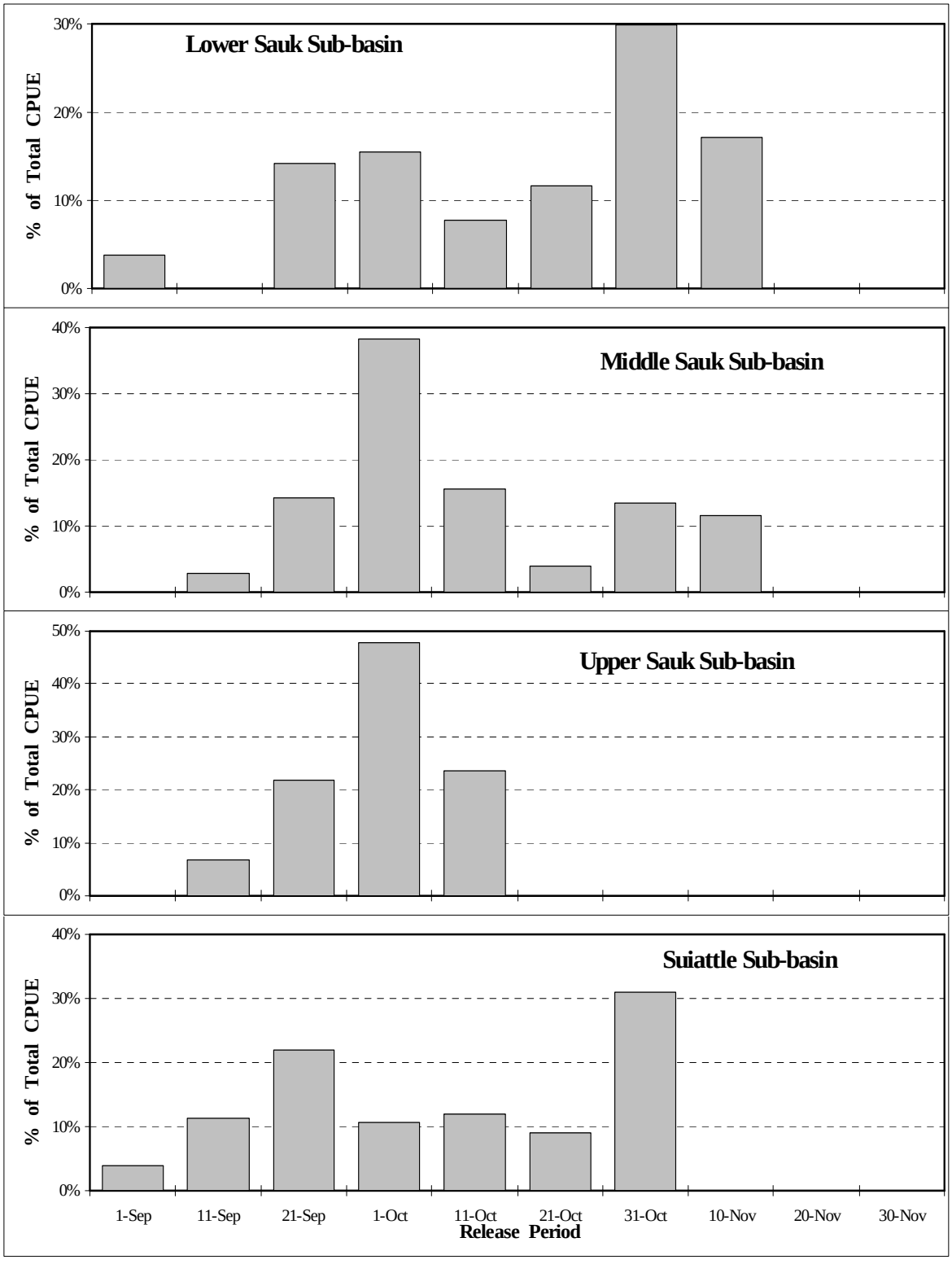

Figure 7. Beach seine catch-per-unit effort (CPUE) of coho salmon bound for major Skagit River tag recovery areas in 1987. CPUE is for ten-day periods (starting date of period shown) and is expressed as a percentage of the total CPUE for tagged fish recovered from the area (continued).

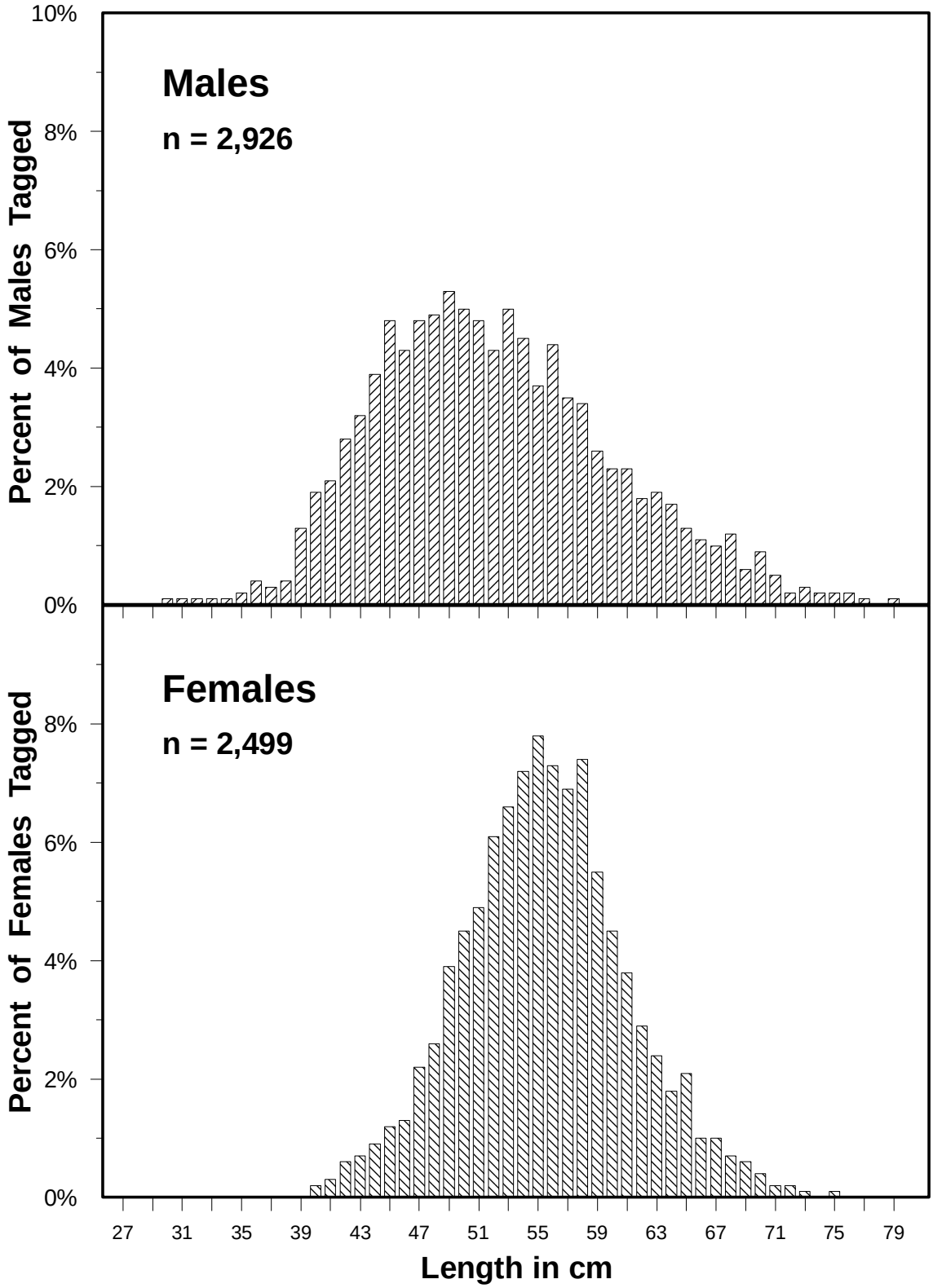

Figure 8. Comparison of length frequencies of male and female coho salmon tagged in the lower Skagit River, 1987.

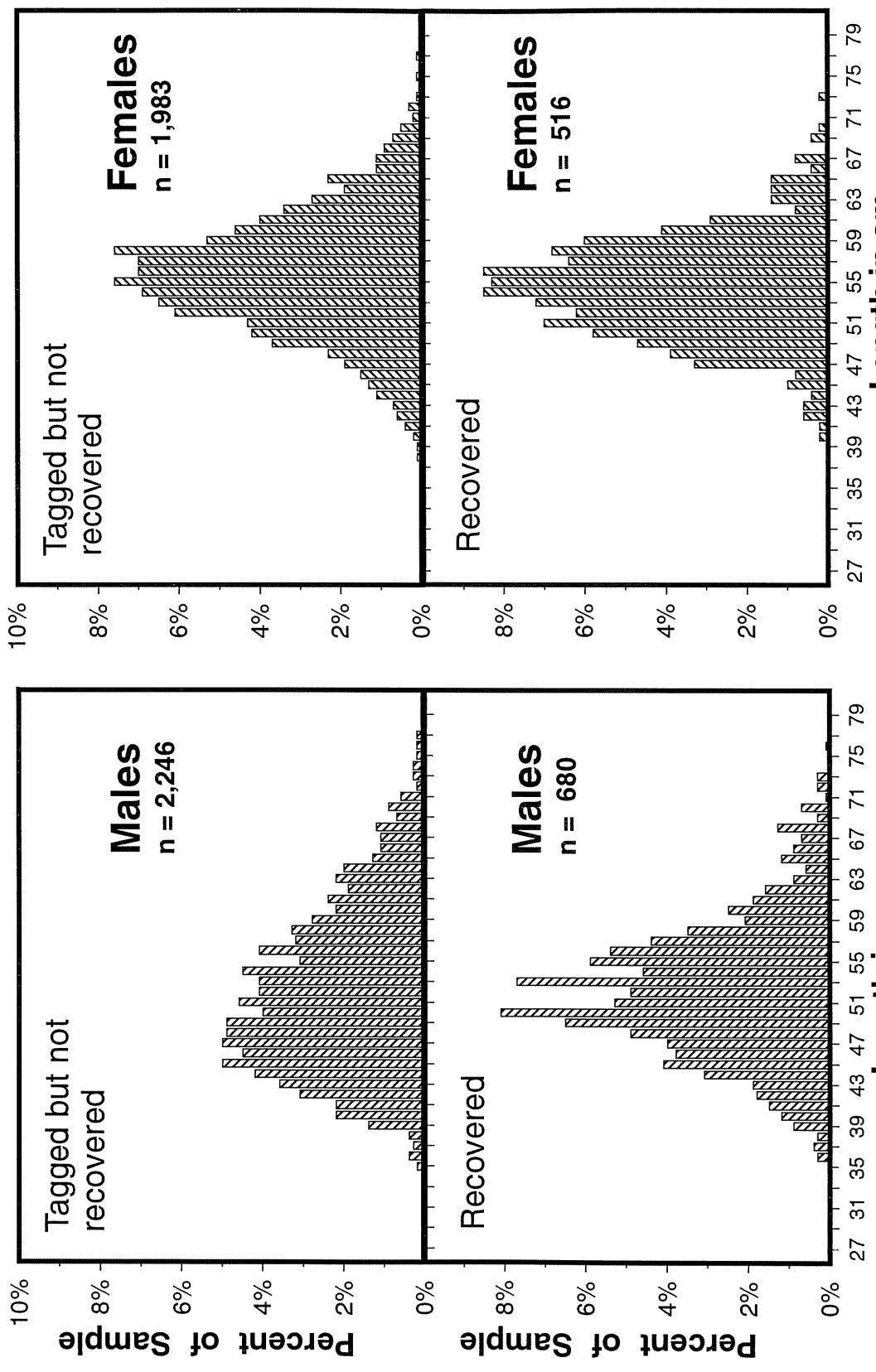

Figure 9. Comparison of length frequencies of coho salmon that were tagged but not recovered to those that were tagged and recovered, for males and females, 1987.

Females Tagged female coho salmon averaged 55.5 cm in fork length (SE = 0.11). The mean length of female coho salmon that were tagged but not recovered was 55.7 cm (SE = 0.13) compared to a mean length of 54.5 cm (SE = 0.22) for female coho salmon that were tagged and recovered. The length distribution of female coho salmon that were tagged but not recovered was significantly different (K-S test, $P < 0.01$) from the distribution of those that were tagged and recovered (Figure 9). Two length categories were defined from the sequential K-S tests for female coho salmon: (1) fish with lengths less than 60 cm; and (2) fish with lengths equal to or greater than 60 cm. The percentages of tagged coho salmon in each length category that were recovered were 22.8% and 13.1%, respectively (Appendix Table A-15).

Tag Recovery Rates There was a significant difference ($P = 0.02$) in tag recovery rates between male and female coho salmon. The highest rate of tag recovery, 29.5%, was for males in the medium (48 to 57 cm) length category (Appendix Table A-15). The lowest tag recovery rate (13.1%) was for females in the largest length category (≥ 60 cm). There was a significant difference (χ^2, $P = 0.10$) in tag recovery rates among the release condition categories. Coho salmon classified as x+ had a 5.6% tag recovery rate while those classified as x had a 22.2% tag recovery rate (Appendix Table A-16). There was not a significant difference (χ^2, $P = 0.12$) in tag recovery rates among the maturity categories.

Sex-Length Composition There were temporal changes in both the sex composition and length composition for each sex during the tagging period (Figure 10). The percentage of males in the tagging samples declined from about 65% to about 48% during the release period and the percentage of females increased. The percentage of small males (< 48 cm) decreased throughout the release period and the percentage of large males (> 57 cm) and large females (> 59 cm) increased.

Conclusions

The tag recovery data indicate that approximately 3% of the coho salmon migrating through the lower river tagging area were caught and tagged. The percentage of tagged or marked coho salmon in the samples from most of the major recovery areas (areas with seven or more tag recoveries) was near 3%: Marblemount 3.3%; Baker River trap 2.7%; commercial fishery 3.2%; Middle Skagit sub-basin 3.4%; Suiattle sub-basin 3.6%; Lower Sauk sub-basin 2.6%; and Upper Sauk sub-basin 3.4%. The exceptions were the samples from the Upper Skagit sub-basin (4.1%), Middle Sauk sub-basin (2.2%), and Cascade sub-basin (1.5%). Significant differences in ρ between samples collected during different time periods were found at Upper Skagit, Lower Sauk, and Middle Sauk sub-basins. This makes interpretation of the overall ρ for these areas uncertain. Similar to 1986, ρ for the sample from the Cascade sub-basin was less than that observed in the majority of the other recovery areas upstream of the tagging site. The tag recovery data indicate that some coho salmon from spawning areas substantially downstream of the tagging site were present in the tagging area. There were eight tags recovered in 1,508 coho salmon examined (0.5%) during spawning ground surveys in the Nookachamps and Carpenter sub-basins.

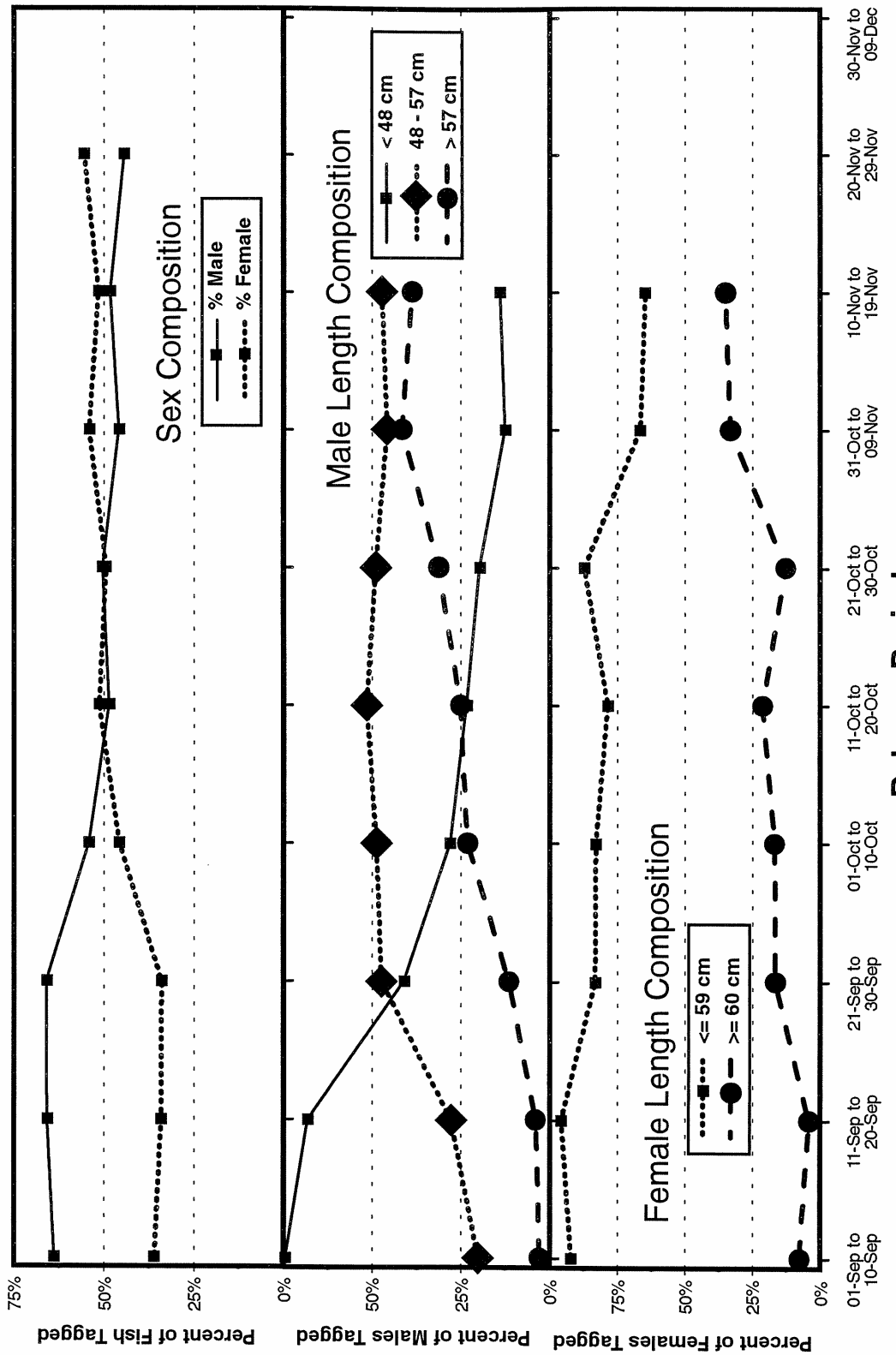

Figure 10. Sex and length composition, by release period, of coho salmon tagged in the lower Skagit River, 1987.

We recommend that the estimate using the pooled Marblemount-Baker-commercial fishery-Middle Skagit-Suiattle-Upper Sauk data be considered the "best" estimate of coho salmon abundance for 1987. There was not a significant difference in ρ among these areas. The samples from two of the areas (Marblemount Hatchery and Baker River trap) are censuses. There were no temporal differences in ρ for the samples from the commercial fishery or the three sub-basins. This estimate uses the largest number of tag recoveries (1,204) and therefore has the smallest CV. We do not recommend combining the data from the Upper Skagit, Middle Sauk, and Lower Sauk sub-basins because of the temporal differences in ρ for the samples from these areas. The estimate, 167,408 coho salmon (95% confidence interval: 158,694 to 177,368), is for the number of fish present in the lower Skagit River tagging area during the period 3 September to 20 November. This estimate includes coho salmon bound for all spawning grounds above the tagging area and some portion of the escapement to areas downstream of the tagging site.

DISCUSSION

The number of coho salmon in the escapement to the Skagit River was estimated using the tag release-and-recovery data and the Petersen model. A discussion of how well the data meet the major assumptions of the Petersen model and a definition of the "population" which is being estimated follows.

Population was Closed

We assume that some coho salmon migrated through the tagging area before and after the period of tagging (3 September through 20 November). Although the Petersen model generally assumes a closed population, the population can be open but the exact point in time to which the estimate applies must be specified (Seber 1982). We feel the trend in CPUE for the beach seine used to capture coho salmon for tagging provides strong evidence that the tagging period encompassed the major portion of the coho salmon migration. The CPUE was low when tagging began and was followed by an increase in CPUE to a peak during the period 1 October through 10 October. There was then a period of declining CPUE followed by another peak in CPUE during the period 31 October through 9 November. This was followed by a decline in CPUE in mid and late November (Figure 6). Only 19 coho salmon were captured during 24 sets conducted on 18, 19, and 20 November (0.79 coho salmon/set).

Similarly to 1986, adjustments were made to the total number of fish examined at Baker River trap to account for early-arriving fish that were not subject to tagging. Therefore, the estimate includes only the portion of the population migrating through the tagging area after tagging began.

If we assume there is recruitment to the population (coho salmon migrating through the tagging area after tagging ends) but no mortality before the fish reach their spawning areas, and there is complete mixing of the fish on the spawning grounds, then the abundance estimate includes coho salmon migrating through the tagging area after the last day of tagging. Sampling at Marblemount Hatchery and at Baker River trap occurred through 15 January. Tag recovery surveys were conducted in most sub-basin spawning grounds until early or mid February. We feel there was sufficient time for coho salmon migrating through the tagging area after tagging had ended to mix with the fish already present on the spawning grounds and at Marblemount Hatchery.

Area Encompassed by the Estimates:

The Petersen model estimates the number of coho salmon migrating though the tagging area in the lower river during the time period defined above. The estimate includes all coho salmon bound for spawning areas above the tagging area (including Marblemount Hatchery and Baker River) and all spawning areas in the Middle Skagit sub-basin above and including Hansen Creek (Figure 1). Even though Hansen Creek is below the tagging area, the percentage of tagged coho salmon found in samples at the trap was not significantly different from samples

collected from other spawning grounds in the Middle Skagit sub-basin and was similar to other upstream spawning areas. However, the tag release-and-recovery data suggest that only a fraction of the coho salmon which spawned in the Carpenter and Nookachamps sub-basins passed through the tagging area. The percentage of tags in the samples from these areas combined, 0.4% (including test fishery samples), was much smaller than in the upstream recovery areas. This indicates that only a portion of the coho salmon from these areas passed through the tagging area. Therefore, we conclude that the abundance estimate does not include all of the coho salmon which spawned in the Carpenter and Nookachamps sub-basins. If the total number of tagged fish that migrated to these downstream areas could be estimated, this number could be removed from the total number of tags released and the abundance estimate would include only coho salmon bound for areas **upstream** of the tagging site and the Middle Skagit sub-basin. We estimated the number of tags "lost" to these downstream areas so that we could examine the effect of these tags on the abundance estimate for the upstream areas.

Estimate of the Number of Tagged Fish "Lost" to Areas Downstream of the Tagging Area:

Three groups of fish from areas downstream of the tagging area were examined for tags: (1) commercial fishery catches; (2) test fishery catches; and (3) fish spawning in the Carpenter and Nookachamps sub-basins. We were not able to allocate the commercial catch in area 78D to its subareas (78D-2, 78D-3, and 78D-4; see Figure 4) in 1987. Therefore, we assumed that the entire 78D commercial catch was included in the abundance estimate. The tag recovery data support this as the total percentage of tags found in commercial fishery samples (ρ = 3.2%) was similar to that observed at most of the upstream recovery areas with seven or more tag recoveries (Table 3). There were no samples inspected for tags from the commercial fishery catches in areas 78C, 8, and 8E (inner Skagit Bay), therefore, we applied the percentage of tags found in downstream test fishery samples (Area 2, Blakes, Bay, and Jetty; see Figure 4) to these catches. The number of tagged fish present on spawning grounds in the Carpenter and Nookachamps sub-basins was estimated by applying the percentage of tags found during in-sample surveys of these sub-basins combined (eight tagged fish found in 1,508 fish examined for ρ = 0.53%) to an independent estimate of the number of coho salmon spawning in these sub-basins. The spawning ground escapement to these sub-basins was estimated using a redd-count method (Conrad et al. 1993). There were also the four out-of-system tag recoveries: three of these recoveries were voluntary and one was recovered as part of a hatchery rack sampling program. The data used to estimate the number of tags lost to downstream areas are summarized in Appendix Table A-17. We estimated that a total of 45 tags could have been "lost" to these downstream areas. If the number of tags released is adjusted to 5,380 (5,425 - 45), then (using the pooled Marblemount-Baker-Middle Skagit-Suiattle-Upper Sauk-commercial fishery recovery data) the estimated abundance for areas upstream of the tagging area becomes 166,020 coho salmon. This is only 1,388 fish less than the "unadjusted" estimate which is less than a one percent difference.

The presence of coho salmon in the tagging area bound for systems outside the Skagit River would also affect the abundance estimate. In 1987, there were only four out-of-system recoveries out of 5,425 coho salmon tagged (0.07%) in the lower Skagit River. Therefore, we do not feel that either: (1) the loss of tagged coho salmon to systems outside the Skagit River or (2) the contribution of coho salmon bound for systems outside the Skagit River to the population being estimated were major sources of error.

All Coho Salmon Have an Equal Probability of Capture During Tagging or the Recovery Sample is a Simple Random Sample of the Population

These assumptions are often hard to satisfy as it is difficult or impossible to obtain simple random samples from highly dispersed and mobile populations. Fortunately, the estimates are still valid under certain alternative assumptions. Junge (1963) demonstrated that selectivity (non-randomness) may exist in both the tagging and recovery samples without introducing bias in the estimate if the sources of selectivity in the two samples are independent.

During the Skagit River study, there is evidence that the tagging sample may not have been random with respect to time. Certain portions of the population may have been tagged at higher rates than others. There is also evidence that the recovery samples on the spawning grounds were selective with respect to the length of the fish, at least for males. Eames et al. (1981, 1983) found that there was a correlation between time of entry and size of coho salmon for the returns to the Skagit River in 1976 and 1977. Smaller fish generally arrived earlier in the run than larger fish. This presents a problem if timing of passage through the tagging area is correlated with the size of fish and area of spawning (Junge 1963). If such selectivity existed the population estimates would contain a negative bias. However, we believe if such a bias exists it is small because the majority of the tag recovery data used for the abundance estimate was collected from areas where there was no size selectivity (Marblemount Hatchery and Baker River trap).

The use of different gears to obtain the tagging and recovery samples is a common technique for minimizing the bias due to selectivity (Ricker 1975; Seber 1982). In this study, coho salmon were captured for tagging using a beach seine. Recovery samples were either a census of all adults returning to an area (Marblemount Hatchery and Baker River trap) and thus non-selective, or were samples collected on the spawning grounds during foot surveys (and to a lesser extent by traps in some areas). We do not feel that selectivity (non-random sampling) was a significant source of bias for the estimates because: (1) the methods used to capture coho salmon for tagging were different from those used to recover them; and (2) a majority of the tag recoveries used to estimate abundance were collected by a census.

Tagging Does Not Affect the Catchability of an Animal

This assumption is necessary because some of the coho salmon passing through the tagging area were subject to an in-river commercial fishery above the tagging area. If jaw-tagged coho salmon were removed at a different rate than untagged fish, the percentage of tags in any recovery samples collected after this removal would be different from the percentage of tags in the population immediately after tagging. There is no evidence of selective removal of tagged fish in the data. In 1987, the percentage of tagged fish in commercial fishery samples from area 78D was essentially the same as that observed at Marblemount Hatchery, Baker River trap, and in samples from most upstream spawning grounds.

Animals Do Not Lose Their Tags Between the First and Second Samples

In 1987, 12% of the tagged coho salmon recovered had missing or illegible tags. However, the use of opercula punches on all tagged fish allowed coho salmon with missing tags to be identified as previously tagged. Identified tag loss must be accounted for only in the Darroch estimate of abundance which requires that the release period of recovered individuals be known. When there was no tag but an operculum punch was present (or the tag was illegible), the release period was estimated as described in the Methods section. This was required only when the Darroch estimate was selected as the appropriate model. The Darroch estimate was used only for the abundance estimates produced from the Upper Skagit, Lower Sauk, and Middle Sauk sub-basin data. The Petersen estimate was selected as the appropriate model for all other estimates including the "best" estimate. As long as all coho salmon with a missing tag are identified by an operculum punch, the Petersen estimate is not affected by the missing tags.

All Tagged Animals are Reported in the Second Sample

Because the majority of the tag recoveries used for the abundance estimates were from Marblemount Hatchery, and all coho salmon at Marblemount Hatchery were inspected twice for tags, we expect very few jaw-tagged (or marked) fish were missed. Live fish were individually inspected for tags and marks at Baker River dam. During surveys of spawning grounds, surveyors carefully inspected each carcass for an operculum punch if no tag was visible. Considering that some carcasses were in an advanced state of decay it is possible that some fish with a missing tag were not identified. In 1987, about 7% of the carcasses examined on the upriver spawning grounds (Middle Skagit sub-basin and above) could not be sampled because of their condition.

There are No Mortalities Due to Tagging

Tests to determine the extent of tagging mortality were conducted during four of the five study years. These tests and their results are documented in Conrad et al. (1997). Based on these tests we concluded that there was no evidence of tagging mortality. The tests provided strong evidence that there was no short-term (within 48 hours) tagging mortality. The tag recovery

data from the commercial fishery samples provide additional evidence that there was no delayed tagging-induced mortality occurring from two weeks up to three months after tagging, either. The average time between tag release and recovery for the commercial fishery recoveries, about 24 days (Table 4), was the shortest of any of the upstream recovery areas. Since the coho salmon caught in the commercial fishery are caught relatively soon after tagging, we would expect that if there is any delayed mortality caused by tagging it would cause the commercial fishery samples to have a higher percentage of tags than the samples that are taken much later, further upstream. In 1987, ρ for the commercial fishery samples (3.2%) was nearly identical to that for Marblemount Hatchery (3.3%). Spawning ground samples from four areas (Middle Skagit, Upper Skagit, Suiattle, and Upper Sauk sub-basins) had values for ρ larger than that of the commercial fishery samples.

CONCLUSIONS

The estimated abundance of coho salmon in 1987 was 167,408 fish with a 95% confidence interval of 158,694 to 177,368 fish. The mark-recapture estimate is for the number of coho salmon migrating through the tagging area after tagging began on 3 September. It includes all coho salmon bound for spawning areas above the tagging area and an unknown fraction of the salmon from spawning areas in the Nookachamps and Carpenter sub-basins. This abundance estimate was very precise (CV = 2.5%) because of the large number of fish examined for tags during in-sample surveys and the relatively high percentage (for mark-recapture estimates) of the total number of fish tagged that were eventually recovered and used for the estimate (18%). To restrict the estimate to spawning areas in the Middle Skagit sub-basin and spawning areas above it, adjustments were made to the number of tags released. Using the adjusted number of tags released, the estimated abundance for this more restricted area was 166,020 coho salmon. The variance of this estimate was not calculated because of the unknown precision for the estimated number of tags "lost" to downstream areas. The adjusted estimate falls within the 95% confidence interval of the original estimate.

To estimate the number of "wild" coho salmon which reached upstream spawning areas in the Skagit River during 1987, the number of hatchery fish plus any catches by the commercial and test fisheries above the tagging area need to be removed from the adjusted estimate and the number of fish which migrated through the tagging area prior to tagging needs to be added. Since fish which migrated through the tagging area before tagging began are included in the spawning ground samples, only prior-migrating fish returning to Baker River or caught in the commercial fishery need to be included. Since the returns to the Baker River trap were censused and the total commercial catch by date is recorded on fish tickets, we have a total count of the prior-migrating fish to these areas: 21 fish to Baker River and 1,036 fish in the commercial fishery. In-population sport catches should also be subtracted from the adjusted estimate. In-river catches of coho salmon by the sport fishery in the Skagit River were estimated to be only 129 fish in 1987 (WDF 1988) and were not included in the summary total as the specific dates and areas of harvest of these fish are unknown. A summary of the total terminal area run of coho salmon to the Skagit River in 1987 is presented in Table 6**. The total terminal area run of coho salmon to the Skagit River in 1987 is estimated to be 180,706, fish. An estimated 137,738 coho salmon were in the "wild" escapement to Skagit River spawning grounds**: 133,088 fish were estimated to have reached upstream spawning grounds and 4,650 coho salmon were estimated for lower river (Nookachamps and Carpenter sub-basin) spawning grounds. For comparison, the escapement of "wild" coho salmon to Skagit River spawning grounds estimated using index area surveys was 33,000 fish (Jeff Parkhurst, WDFW, personal communication). This estimate is two-thirds smaller than the tagging estimate. An alternative estimate, derived from CWT recoveries in the test fisheries and trap recoveries (Hayman 1996), was for a wild escapement of 85,000 to 96,000 fish (depending upon the hatchery stray rate assumed); this estimate was subsequently refined for a wild escapement estimate of 86,000 fish (Hayman 1997). Using a redd-count method, Conrad et al. (1993) estimated the wild escapement to be 81,000 to 121,000 fish (depending upon the number of coho salmon per redd assumed).

Table 6. Summary of the number of coho salmon returning to Skagit Bay in 1987.

Component	In-Population	Out of Population	Total
Upstream Estimated Total	166,020	1,076	167,096
Marblemount Hatchery	29,277	0	29,277
Baker River Hatchery[a]	1,561	15	1,576
Area 78D Commercial Catch	2,119	1,036	3,155
Upstream Test Fishery Catch	0	0	0
Upstream Removals and Hatchery Fish	32,957	1,051	34,008
Estimated "Wild" Escapement to Upstream Spawning Areas	133,063	25	133,088
Nookachamps Sub-basin Estimated Escapement		3,339	3,339
Carpenter Sub-basin Estimated Escapement		1,311	1,311
Areas 78C, 8E, 8 Commercial Catches		7,594	7,594
Downstream Test Fishery Catch		1,366	1,366
Downstream Total		13,610	13,610
"Wild" Escapement[b] to Spawning Grounds	133,063	4,675	137,738[c]
Total Terminal Run to Skagit Bay	166,020	14,686	180,706[c]

[a] Estimated total number of hatchery coho salmon that returned to Baker River trap. The release of hatchery smolts for the 1984 brood year (which primarily returned during 1987) was not adipose fin clipped. Therefore, the total number of adult fish of hatchery origin in the 1987 return (1,576) was estimated by multiplying the historic average return rate for hatchery smolts to Baker River by the number of smolts released (Tim Flint, WDFW, personal communication). Since the total return to the Baker River trap was 4,116, the estimated escapement of wild coho salmon was the remainder, or 2,540 coho. Of the total return to Baker River, 40 returned prior to tagging and were considered out of population. The hatchery:wild composition of these 40 out-of-population coho was assumed to be the same as for the total Baker River trap return; thus we estimated that 15 of these fish were hatchery fish and 25 were wild coho salmon. The wild totals are included in the "wild" escapement numbers.

[b] Includes estimated "wild" escapement to upstream spawning areas and estimated escapement to the Nookachamps and Carpenter sub-basins (from Conrad et. al 1993).

[c] The estimated catch by the in-river sport fishery was 129 coho salmon, but the specific dates and areas of harvest of these fish are unknown. The total wild escapement should be reduced by the number of coho salmon caught in the sport fishery in upstream areas after tagging began. The total terminal run should be increased by the number caught in downstream areas or before tagging started.

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APPENDIX A

Summary tables of sample data for 1987.

Appendix Table A-1. Summary of coho salmon escapement samples collected at Marblemount Hatchery in 1987.

Sample Date	Sample Method	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
27-Oct	Pond Mortality	2	1	50.0%
	Mortality Test	25	0	0.0%
	Total	27	1	3.7%
16-Nov	Pond Mortality	24	7	29.2%
	Surplused	1,306	27	2.1%
	Total	1,330	34	2.6%
17-Nov	Surplused	1,766	75	4.2%
23-Nov	Spawned	1,667	81	4.9%
24-Nov	Spawned	1,484	61	4.1%
25-Nov	Spawned	572	29	5.1%
30-Nov	Pond Mortality	190	37	19.5%
	Surplused	2,808	108	3.8%
	Total	2,998	145	4.8%
1-Dec	Surplused	30	0	0.0%
8-Dec	Pond Mortality	8	0	0.0%
	Surplused	799	19	2.4%
	Spawned	1,054	40	3.8%
	Total	1,861	59	3.2%
14-Dec	Surplused	2,741	71	2.6%
16-Dec	Pond Mortality	330	26	7.9%
	Spawned	1,392	34	2.4%
	Total	1,722	60	3.5%
17-Dec	Pond Mortality	316	10	3.2%
	Spawned	1,540	41	2.7%
	Total	1,856	51	2.7%
21-Dec	Surplused	4,280	95	2.2%
22-Dec	Surplused	3,921	104	2.7%
23-Dec	Pond Mortality	167	11	6.6%
	Surplused	1,903	53	2.8%
	Total	2,070	64	3.1%
4-Jan	Spawned	437	16	3.7%
15-Jan	Pond Mortality	72	7	9.7%
	Spawned	443	9	2.0%
	Total	515	16	3.1%
Subtotals	Pond Mortality	1,109	99	8.9%
	Surplused	19,554	552	2.8%
	Spawned	8,589	311	3.6%
	Mortality Test	25	0	0.0%
	IN-SAMPLE TOTAL	29,277	962	3.3%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-2. Summary of coho salmon escapement samples collected at Baker River trap in 1987.

Sample Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
11-Sep	21	0	0.0%
18-Sep	63	0	0.0%
23-Sep	91	0	0.0%
25-Sep	47	0	0.0%
30-Sep	206	1	0.5%
2-Oct	146	2	1.4%
5-Oct	186	2	1.1%
7-Oct	129	2	1.6%
9-Oct	71	2	2.8%
12-Oct	277	3	1.1%
13-Oct	64	0	0.0%
14-Oct	60	2	3.3%
16-Oct	54	0	0.0%
19-Oct	127	2	1.6%
21-Oct	80	3	3.8%
23-Oct	70	4	5.7%
26-Oct	91	1	1.1%
28-Oct	118	1	0.8%
30-Oct	31	0	0.0%
2-Nov	88	5	5.7%
4-Nov	430	15	3.5%
5-Nov	44	0	0.0%
6-Nov	68	3	4.4%
9-Nov	129	5	3.9%
10-Nov	139	3	2.2%
12-Nov	136	4	2.9%
13-Nov	250	10	4.0%
14-Nov	124	10	8.1%
16-Nov	195	7	3.6%
18-Nov	101	5	5.0%
20-Nov	92	5	5.4%
23-Nov	72	5	6.9%
25-Nov	96	5	5.2%
30-Nov	23	1	4.3%
2-Dec	26	2	7.7%
4-Dec	37	0	0.0%
7-Dec	38	0	0.0%
9-Dec	22	1	4.5%
11-Dec	20	0	0.0%
16-Dec	12	0	0.0%
18-Dec	4	0	0.0%
23-Dec	9	0	0.0%
30-Dec	4	0	0.0%
8-Jan	3	0	0.0%
15-Jan	3	0	0.0%
IN-SAMPLE TOTAL	4,076	111	2.7%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-3. Summary of coho salmon catch samples collected from the commercial fishery in area 78D, 1987.

Sample Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
9-Sep	30	0	0.0%
10-Sep	94	0	0.0%
11-Sep	45	0	0.0%
17-Nov	72	8	11.1%
18-Nov	161	8	5.0%
21-Dec	86	5	5.8%
22-Dec	8	0	0.0%
23-Dec	55	0	0.0%
28-Dec	5	0	0.0%
29-Dec	132	2	1.5%
30-Dec	36	1	2.8%
13-Jan	24	0	0.0%
20-Jan	6	0	0.0%
IN-SAMPLE TOTAL	754	24	3.2%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-4. Summary of coho salmon catch samples collected during test fisheries in the Skagit River, 1987.

	Area 2			Blakes			Bay and Jetty		
Sample Date	Number Examined	# Tags Found[a]	ρ	Number Examined	# Tags Found[a]	ρ	Number Examined	# Tags Found[a]	ρ
17-Sep				108	0	0.0%	92	0	0.0%
22-Sep	30	1	3.3%						
23-Sep				108	0	0.0%	47	0	0.0%
29-Sep	70	0	0.0%						
30-Sep				145	0	0.0%	62	1	1.6%
7-Oct	45	0	0.0%	196	0	0.0%	10	0	0.0%
13-Oct	12	0	0.0%						
15-Oct				115	0	0.0%	73	0	0.0%
21-Oct	39	0	0.0%						
22-Oct				54	0	0.0%	31	0	0.0%
28-Oct				38	0	0.0%	5	0	0.0%
30-Oct	52	1	1.9%						
4-Nov							1	0	0.0%
5-Nov				25	0	0.0%	2	0	0.0%
IN-SAMPLE TOTAL	248	2	0.8%	789	0	0.0%	323	1	0.3%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-5. Summary of coho salmon escapement samples from the Middle Skagit sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, and at the Hansen Creek trap, 1987.

	SSC SURVEYS			WDFW SURVEYS			HANSEN CREEK TRAP			SAMPLES COMBINED		
Survey Date	Number Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)
16-Nov	1	0	0.0%							1	0	0.0%
18-Nov				2	0	0.0%				2	0	0.0%
23-Nov							28	1	3.6%	28	1	3.6%
24-Nov	3	0	0.0%				66	1	1.5%	69	1	1.4%
25-Nov				1	0	0.0%	25	1	4.0%	26	1	3.8%
27-Nov							5	1	20.0%	5	1	20.0%
30-Nov	1	0	0.0%							1	0	0.0%
1-Dec	10	1	10.0%							10	1	10.0%
2-Dec	9	0	0.0%				1	0	0.0%	10	0	0.0%
3-Dec				32	0	0.0%	6	0	0.0%	38	0	0.0%
4-Dec							46	3	6.5%	46	3	6.5%
5-Dec							12	0	0.0%	12	0	0.0%
6-Dec							10	1	10.0%	10	1	10.0%
7-Dec							7	0	0.0%	7	0	0.0%
8-Dec							8	0	0.0%	8	0	0.0%
9-Dec							6	0	0.0%	6	0	0.0%
10-Dec	2	0	0.0%	1	0	0.0%	5	1	20.0%	8	1	12.5%
11-Dec	4	0	0.0%	5	0	0.0%	93	0	0.0%	102	0	0.0%
12-Dec							13	0	0.0%	13	0	0.0%
14-Dec				18	0	0.0%	13	0	0.0%	31	0	0.0%
15-Dec	36	0	0.0%	47	3	6.4%	1	0	0.0%	84	3	3.6%
16-Dec	5	0	0.0%	48	5	10.4%				53	5	9.4%
17-Dec				21	0	0.0%				21	0	0.0%
18-Dec	20	5	25.0%				6	0	0.0%	26	5	19.2%
21-Dec	1	1	100.0%				6	0	0.0%	7	1	14.3%
22-Dec	38	0	0.0%							38	0	0.0%
23-Dec	8	0	0.0%				2	0	0.0%	10	0	0.0%
28-Dec				237	8	3.4%				237	8	3.4%
29-Dec	48	1	2.1%	36	1	2.8%				84	2	2.4%
30-Dec	34	0	0.0%							34	0	0.0%

- continued -

Appendix Table A-5. Summary of coho salmon escapement samples from the Middle Skagit sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, and at the Hansen Creek trap, 1987 (continued).

	SSC SURVEYS			WDFW SURVEYS			HANSEN CREEK TRAP			SAMPLES COMBINED		
Survey Date	Number Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)
5-Jan	1	0	0.0%							1	0	0.0%
6-Jan	6	0	0.0%							6	0	0.0%
7-Jan	4	1	25.0%	30	2	6.7%				34	3	8.8%
8-Jan	52	2	3.8%	143	0	0.0%				195	2	1.0%
9-Jan	2	0	0.0%							2	0	0.0%
10-Jan	1	0	0.0%				2	0	0.0%	3	0	0.0%
11-Jan	4	0	0.0%				1	0	0.0%	5	0	0.0%
12-Jan	15	1	6.7%							15	1	6.7%
13-Jan	149	7	4.7%							149	7	4.7%
15-Jan	2	0	0.0%				4	0	0.0%	6	0	0.0%
16-Jan							1	0	0.0%	1	0	0.0%
17-Jan							2	0	0.0%	2	0	0.0%
18-Jan	2	0	0.0%							2	0	0.0%
19-Jan	3	0	0.0%							3	0	0.0%
20-Jan	1	0	0.0%							1	0	0.0%
21-Jan	3	0	0.0%							3	0	0.0%
22-Jan	2	0	0.0%							2	0	0.0%
24-Jan	9	1	11.1%							9	1	11.1%
25-Jan	19	2	10.5%							19	2	10.5%
26-Jan							0	0	0.0%	0	0	0.0%
27-Jan	2	1	50.0%							2	1	50.0%
28-Jan				2	0	0.0%				2	0	0.0%
29-Jan	2	0	0.0%							2	0	0.0%
1-Feb	1	0	0.0%							1	0	0.0%
2-Feb	4	0	0.0%							4	0	0.0%
10-Feb	1	0	0.0%							1	0	0.0%
IN-SAMPLE TOTAL	505	23	4.6%	623	19	3.0%	369	9	2.4%	1,497	51	3.4%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-6. Summary of coho salmon escapement samples from the Upper Skagit sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, and at a trap on Barnaby Slough, 1987.

	SSC SURVEYS			WDFW SURVEYS			BARNABY SLOUGH TRAP			SAMPLES COMBINED		
Survey Date	Number Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)
16-Nov				2	0	0.0%				2	0	0.0%
25-Nov				3	0	0.0%				3	0	0.0%
30-Nov	2	1	50.0%							2	1	50.0%
1-Dec	19	1	5.3%							19	1	5.3%
2-Dec	4	1	25.0%	20	3	15.0%				24	4	16.7%
4-Dec	10	3	30.0%				3	0	0.0%	13	3	23.1%
5-Dec							3	0	0.0%	3	0	0.0%
7-Dec	32	3	9.4%				9	0	0.0%	41	3	7.3%
8-Dec				24	2	8.3%	10	1	10.0%	34	3	8.8%
Subtotal	67	9	13.4%	49	5	10.2%	25	1	4.0%	141	15	10.6%
9-Dec							2	0	0.0%	2	0	0.0%
10-Dec	16	1	6.3%	14	0	0.0%	3	0	0.0%	33	1	3.0%
11-Dec	21	1	4.8%				4	0	0.0%	25	1	4.0%
12-Dec							1	0	0.0%	1	0	0.0%
13-Dec							2	0	0.0%	2	0	0.0%
14-Dec	3	1	33.3%				1	0	0.0%	4	1	25.0%
15-Dec	83	3	3.6%							83	3	3.6%
17-Dec				69	5	7.2%				69	5	7.2%
18-Dec	15	1	6.7%							15	1	6.7%
21-Dec	71	5	7.0%	57	3	5.3%				128	8	6.3%
22-Dec	45	3	6.7%							45	3	6.7%
23-Dec							3	0	0.0%	3	0	0.0%
26-Dec							1	0	0.0%	1	0	0.0%
28-Dec	104	3	2.9%	78	0	0.0%	1	0	0.0%	183	3	1.6%
29-Dec	187	8	4.3%				2	0	0.0%	189	8	4.2%
30-Dec							9	0	0.0%	9	0	0.0%
31-Dec	160	4	2.5%							160	4	2.5%
4-Jan	38	1	2.6%							38	1	2.6%
6-Jan	55	3	5.5%							55	3	5.5%
7-Jan	139	6	4.3%	5	0	0.0%				144	6	4.2%

- continued -

Appendix Table A-6. Summary of coho salmon escapement samples from the Upper Skagit sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, and at a trap on Barnaby Slough, 1987 (continued).

	SSC SURVEYS			WDFW SURVEYS			BARNABY SLOUGH TRAP			SAMPLES COMBINED		
Survey Date	Number Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)
8-Jan	91	2	2.2%	11	0	0.0%	11	2	18.2%	113	4	3.5%
11-Jan	5	0	0.0%							5	0	0.0%
12-Jan	17	0	0.0%							17	0	0.0%
13-Jan	36	3	8.3%							36	3	8.3%
14-Jan	22	1	4.5%							22	1	4.5%
15-Jan				4	0	0.0%	15	0	0.0%	19	0	0.0%
19-Jan	19	0	0.0%							19	0	0.0%
20-Jan	77	1	1.3%							77	1	1.3%
21-Jan	11	0	0.0%							11	0	0.0%
22-Jan				3	0	0.0%	10	1	10.0%	13	1	7.7%
25-Jan	17	0	0.0%							17	0	0.0%
26-Jan	39	0	0.0%							39	0	0.0%
27-Jan	46	2	4.3%							46	2	4.3%
28-Jan	7	0	0.0%							7	0	0.0%
29-Jan	59	3	5.1%	4	0	0.0%	3	1	3.3%	66	4	6.1%
3-Feb	59	0	0.0%							59	0	0.0%
4-Feb	22	0	0.0%	4	0	0.0%				26	0	0.0%
5-Feb	10	1	10.0%							10	1	10.0%
8-Feb	3	0	0.0%							3	0	0.0%
9-Feb	40	0	0.0%							40	0	0.0%
Subtotal	1,517	53	3.5%	249	8	3.2%	68	4	5.9%	1,834	65	3.5%
IN-SAMPLE TOTAL	1,584	62	3.9%	298	13	4.4%	93	5	5.4%	1,975	80	4.1%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-7. Summary of coho salmon escapement samples from the Lower Sauk sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, 1987.

	SSC SURVEYS			WDFW SURVEYS			SURVEYS COMBINED		
Survey Date	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ
30-Nov	2	0	0.0%				2	0	0.0%
7-Dec	12	3	25.0%				12	3	25.0%
14-Dec	15	0	0.0%				15	0	0.0%
16-Dec				26	2	7.7%	26	2	7.7%
22-Dec	115	6	5.2%				115	6	5.2%
24-Dec				18	2	11.1%	18	2	11.1%
Subtotal	144	9	6.2%	44	4	9.1%	188	13	6.9%
29-Dec	148	2	1.4%	110	2	1.8%	258	4	1.6%
4-Jan	58	0	0.0%				58	0	0.0%
7-Jan				10	0	0.0%	10	0	0.0%
11-Jan				45	0	0.0%	45	0	0.0%
12-Jan	32	1	3.1%				32	1	3.1%
18-Jan	16	0	0.0%				16	0	0.0%
26-Jan	29	1	3.4%	11	0	0.0%	40	1	2.5%
4-Feb	94	1	1.1%				94	1	1.1%
8-Feb	32	0	0.0%				32	0	0.0%
Subtotal	409	5	1.2%	176	2	1.1%	585	7	1.2%
IN-SAMPLE TOTAL	553	14	2.5%	220	6	2.7%	773	20	2.6%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-8. Summary of coho salmon escapement samples from the Middle Sauk sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, 1987.

	SSC SURVEYS			WDFW SURVEYS			SURVEYS COMBINED		
Survey Date	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ	Number Examined	Tags Found[a]	ρ
18-Nov				1	0	0.0%	1	0	0.0%
30-Nov				68	4	5.9%	68	4	5.9%
2-Dec	17	1	5.9%				17	1	5.9%
4-Dec				6	1	16.7%	6	1	16.7%
7-Dec	7	0	0.0%	11	0	0.0%	18	0	0.0%
9-Dec				1	0	0.0%	1	0	0.0%
16-Dec	107	3	2.8%	164	4	2.4%	271	7	2.6%
17-Dec				14	0	0.0%	14	0	0.0%
18-Dec	53	3	5.7%				53	3	5.7%
Subtotal	184	7	3.8%	265	9	3.4%	449	16	3.6%
22-Dec	390	5	1.3%				390	5	1.3%
23-Dec	41	1	2.4%				41	1	2.4%
28-Dec	19	0	0.0%				19	0	0.0%
29-Dec				244	2	0.8%	244	2	0.8%
30-Dec	229	3	1.3%				229	3	1.3%
1-Jan	23	0	0.0%				23	0	0.0%
6-Jan	65	1	1.5%				65	1	1.5%
7-Jan	82	2	2.4%				82	2	2.4%
11-Jan				32	2	6.3%	32	2	6.3%
13-Jan	79	4	5.1%				79	4	5.1%
19-Jan				5	0	0.0%	5	0	0.0%
20-Jan	21	3	14.3%				21	3	14.3%
22-Jan	27	1	3.7%				27	1	3.7%
26-Jan	1	0	0.0%	29	0	0.0%	30	0	0.0%
27-Jan	6	0	0.0%				6	0	0.0%
28-Jan	46	1	2.2%				46	1	2.2%
1-Feb				36	0	0.0%	36	0	0.0%
2-Feb	30	0	0.0%	16	0	0.0%	46	0	0.0%
4-Feb	7	0	0.0%				7	0	0.0%
8-Feb	6	0	0.0%				6	0	0.0%
10-Feb	13	1	7.7%				13	1	7.7%
Subtotal	1,085	22	2.0%	362	4	1.1%	1,447	26	1.8%
IN-SAMPLE TOTAL	1,269	29	2.3%	627	13	2.1%	1,896	42	2.2%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-9. Summary of coho salmon escapement samples from the Upper Sauk sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1987.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
2-Dec	68	6	8.8%
9-Dec	104	2	1.9%
15-Dec	35	1	2.9%
16-Dec	9	0	0.0%
17-Dec	61	2	3.3%
20-Dec	55	1	1.8%
22-Dec	72	1	1.4%
23-Dec	7	1	14.3%
1-Jan	33	1	3.0%
6-Jan	5	0	0.0%
7-Jan	36	1	2.8%
15-Jan	5	0	0.0%
16-Jan	9	0	0.0%
22-Jan	8	0	0.0%
26-Jan	1	0	0.0%
27-Jan	8	1	12.5%
2-Feb	6	1	16.7%
IN-SAMPLE TOTAL	522	18	3.4%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-10. Summary of coho salmon escapement samples from the Suiattle sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1987.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
24-Nov	3	0	0.0%
1-Dec	9	0	0.0%
8-Dec	49	2	4.1%
9-Dec	77	4	5.2%
15-Dec	50	3	6.0%
18-Dec	2	0	0.0%
21-Dec	127	7	5.5%
22-Dec	64	1	1.6%
27-Dec	31	0	0.0%
28-Dec	115	3	2.6%
29-Dec	125	5	4.0%
5-Jan	173	6	3.5%
14-Jan	79	1	1.3%
21-Jan	13	0	0.0%
22-Jan	1	0	0.0%
25-Jan	46	3	6.5%
27-Jan	24	1	4.2%
1-Feb	42	0	0.0%
4-Feb	2	0	0.0%
10-Feb	19	2	10.5%
IN-SAMPLE TOTAL	1,051	38	3.6%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-11. Summary of coho salmon escapement samples from the Nookachamps sub-basin collected during spawning ground surveys by Skagit System Cooperative (SSC) and Washington Department of Fish and Wildlife (WDFW) crews, and at a trap on the East Fork, 1987.

	SSC SURVEYS			WDFW SURVEYS			EAST FORK TRAP			SAMPLES COMBINED		
Survey Date	Number Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)	Fish Exam.	Tags Found[a]	% w/Tags (ρ)
3-Nov				1	0	0.0%				1	0	0.0%
18-Nov				16	0	0.0%				16	0	0.0%
25-Nov				1	0	0.0%				1	0	0.0%
30-Nov	1	0	0.0%							1	0	0.0%
3-Dec				31	0	0.0%	9	0	0.0%	40	0	0.0%
4-Dec				24	1	4.2%	1	0	0.0%	25	1	4.0%
7-Dec							14	1	7.1%	14	1	7.1%
8-Dec	28	0	0.0%				6	0	0.0%	34	0	0.0%
9-Dec				18	0	0.0%				18	0	0.0%
11-Dec							2	0	0.0%	2	0	0.0%
14-Dec	2	0	0.0%	7	0	0.0%				9	0	0.0%
17-Dec	5	0	0.0%	55	0	0.0%				60	0	0.0%
18-Dec	114	2	0.9%							114	2	0.9%
21-Dec	13	0	0.0%							13	0	0.0%
23-Dec	102	0	0.0%							102	0	0.0%
28-Dec	21	0	0.0%							21	0	0.0%
29-Dec	56	0	0.0%	152	0	0.0%				208	0	0.0%
31-Dec	96	2	2.1%							96	2	2.1%
5-Jan	10	0	0.0%							10	0	0.0%
6-Jan	25	0	0.0%							25	0	0.0%
7-Jan	90	0	0.0%							90	0	0.0%
8-Jan			0.0%	36	0	0.0%				36	0	0.0%
11-Jan	147	0	0.0%							147	0	0.0%
12-Jan	16	0	0.0%							16	0	0.0%
19-Jan	38	2	5.3%							38	2	5.3%
26-Jan	14	0	0.0%							14	0	0.0%
3-Feb	8	0	0.0%							8	0	0.0%
IN-SAMPLE TOTAL	786	6	0.8%	341	1	0.3%	32	1	3.1%	1,159	8	0.7%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-12. Summary of coho salmon escapement samples from the Carpenter sub-basin collected during spawning ground surveys by Skagit System Cooperative crews and at traps on Fisher Creek and Carpenter Creek Slough, 1987.

	SURVEYS			SUB-BASIN TRAPS[a]			SAMPLES COMBINED		
Survey Date	Number Examined	Tags Found[b]	ρ	Number Examined	Tags Found[b]	ρ	Number Examined	Tags Found[b]	ρ
5-Nov				1	0	0.0%	1	0	0.0%
8-Nov				1	0	0.0%	1	0	0.0%
12-Nov				1	0	0.0%	1	0	0.0%
13-Nov				7	0	0.0%	7	0	0.0%
23-Nov				3	0	0.0%	3	0	0.0%
24-Nov				7	0	0.0%	7	0	0.0%
25-Nov				4	0	0.0%	4	0	0.0%
2-Dec	11	0	0.0%				11	0	0.0%
4-Dec				1	0	0.0%	1	0	0.0%
6-Dec				4	0	0.0%	4	0	0.0%
7-Dec				4	0	0.0%	4	0	0.0%
8-Dec				7	0	0.0%	7	0	0.0%
9-Dec				3	0	0.0%	3	0	0.0%
10-Dec	2[c]	0	0.0%	6	0	0.0%	8	0	0.0%
11-Dec	13	0	0.0%	1	0	0.0%	14	0	0.0%
12-Dec				2	0	0.0%	2	0	0.0%
14-Dec	3[c]	0	0.0%				3	0	0.0%
16-Dec	4	0	0.0%				4	0	0.0%
17-Dec	6	0	0.0%				6	0	0.0%
18-Dec	37	0	0.0%				37	0	0.0%
21-Dec	3	0	0.0%				3	0	0.0%
22-Dec	4	0	0.0%				4	0	0.0%
23-Dec	9	0	0.0%				9	0	0.0%
29-Dec				6	0	0.0%	6	0	0.0%
30-Dec	37	0	0.0%				37	0	0.0%
31-Dec	33	0	0.0%	4	0	0.0%	37	0	0.0%
2-Jan	2	0	0.0%	5	0	0.0%	7	0	0.0%
4-Jan	33	0	0.0%				33	0	0.0%
6-Jan	13	0	0.0%	2	0	0.0%	15	0	0.0%
8-Jan				2	0	0.0%	2	0	0.0%
10-Jan				2	0	0.0%	2	0	0.0%
13-Jan	26	0	0.0%	1	0	0.0%	27	0	0.0%
14-Jan	9	0	0.0%				9	0	0.0%
15-Jan	6	0	0.0%	2	0	0.0%	8	0	0.0%
21-Jan	2	0	0.0%				2	0	0.0%
22-Jan	1	0	0.0%				1	0	0.0%
25-Jan	5	0	0.0%				5	0	0.0%
26-Jan	9	0	0.0%				9	0	0.0%
28-Jan	2	0	0.0%				2	0	0.0%
2-Feb	3	0	0.0%				3	0	0.0%
IN-SAMPLE TOTAL	273	0	0.0%	76	0	0.0%	349	0	0.0%

[a] Samples from 5 November through 25 November from Carpenter Creek Slough. Samples from 4 December through 15 January from Fisher Creek.

[b] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

[c] WDFW survey.

Appendix Table A-13. Summary of coho salmon escapement samples from the Cascade sub-basin collected during spawning ground surveys by Skagit System Cooperative crews, 1987.

Survey Date	Number of Fish Examined	Number of Tags Found[a]	% with Tags (ρ)
19-Nov	71	1	1.4%
20-Nov	52	0	0.0%
3-Dec	25	0	0.0%
4-Dec	12	0	0.0%
17-Dec	30	0	0.0%
18-Dec	41	2	4.9%
21-Dec	25	0	0.0%
22-Dec	50	1	2.0%
28-Dec	78	1	1.3%
5-Jan	81	3	3.7%
6-Jan	41	0	0.0%
7-Jan	62	1	1.6%
11-Jan	6	0	0.0%
15-Jan	2	0	0.0%
19-Jan	5	0	0.0%
25-Jan	16	0	0.0%
IN-SAMPLE TOTAL	597	9	1.5%

[a] Includes fish recovered with no tag but having the secondary mark (an opercula punch) or having an illegible tag.

Appendix Table A-14. CPUE (catch per beach seine set) of coho salmon bound for major recovery areas in the Skagit River, 1987. CPUE for recovery areas estimated using in-sample tag recoveries.

Recoveries by release strata.

Tag Release Period	Number of Sets	Coho Catch	Catch/ Set	MM Hatchery	Baker R. Trap	Middle Skagit	Upper Skagit	Lower Sauk	Middle Sauk	Upper Sauk	Suiattle
1. 01-Sep to 10-Sep	70	108	1.5	2	2	1	1	1	0	0	2
2. 11-Sep to 20-Sep	62	500	8.1	45	17	1	1	0	1	1	5
3. 21-Sep to 30-Sep	38	687	18.1	102	10	0	8	2	3	2	6
4. 01-Oct to 10-Oct	52	1,662	32.0	287	32	3	22	3	11	6	4
5. 11-Oct to 20-Oct	35	599	17.1	103	13	3	8	1	3	2	3
6. 21-Oct to 30-Oct	46	438	9.5	96	13	1	6	2	1	0	3
7. 31-Oct to 09-Nov	27	908	33.6	173	11	6	10	3	2	0	6
8. 10-Nov to 19-Nov	47	653	13.9	78	3	18	6	3	3	0	0
9. 20-Nov to 29-Nov	9	9	1.0	0	0	0	0	0	0	0	0
10. 30-Nov to 09-Dec	1	0	0.0	0	0	0	0	0	0	0	0
Totals	387	5,564	14.4	886	101	33	62	15	24	11	29

CPUE apportioned to major recovery areas.

Release Period	MM Hatchery	Baker R. Trap	Middle Skagit	Upper Skagit	Lower Sauk	Middle Sauk	Upper Sauk	Suiattle
1	0.03	0.03	0.01	0.01	0.01	0.00	0.00	0.03
2	0.73	0.27	0.02	0.02	0.00	0.02	0.02	0.08
3	2.68	0.26	0.00	0.21	0.05	0.08	0.05	0.16
4	5.52	0.62	0.06	0.42	0.06	0.21	0.12	0.08
5	2.94	0.37	0.09	0.23	0.03	0.09	0.06	0.09
6	2.09	0.28	0.02	0.13	0.04	0.02	0.00	0.07
7	6.41	0.41	0.22	0.37	0.11	0.07	0.00	0.22
8	1.66	0.06	0.38	0.13	0.06	0.06	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	22.05	2.31	0.80	1.52	0.37	0.55	0.24	0.72

- continued -

Appendix Table A-14. CPUE (catch per beach seine set) of coho salmon from major recovery areas in the Skagit River, 1987 (continued). CPUE apportioned using in-sample tag recoveries.

CPUE standardized as a percentage of total for area.

Release Period	MM Hatchery	Baker R. Trap	Middle Skagit	Upper Skagit	Lower Sauk	Middle Sauk	Upper Sauk	Suiattle
1	0.1%	1.2%	1.8%	0.9%	3.8%	0.0%	0.0%	4.0%
2	3.3%	11.9%	2.0%	1.1%	0.0%	2.9%	6.7%	11.2%
3	12.2%	11.4%	0.0%	13.8%	14.2%	14.3%	21.8%	22.0%
4	25.0%	26.7%	7.2%	27.8%	15.5%	38.3%	47.8%	10.7%
5	13.3%	16.1%	10.7%	15.0%	7.7%	15.5%	23.7%	12.0%
6	9.5%	12.3%	2.7%	8.6%	11.7%	3.9%	0.0%	9.1%
7	29.1%	17.7%	27.8%	24.3%	29.9%	13.4%	0.0%	31.0%
8	7.5%	2.8%	47.8%	8.4%	17.2%	11.6%	0.0%	0.0%
9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Appendix Table A-15. Summary of the number of tag releases and number of in-sample tag recoveries by length for male and female coho salmon tagged in the lower Skagit River, 1987.

	MALES			FEMALES		
Length in cm	Number Released	Number Recovered	Percent Recovered	Number Released	Number Recovered	Percent Recovered
≤ 35	19	0	0.0%	0	0	0.0%
36	12	2	16.7%	0	0	0.0%
37	10	3	30.0%	0	0	0.0%
38	11	2	18.2%	1	0	0.0%
39	38	6	15.8%	1	0	0.0%
40	57	8	14.0%	4	1	0.0%
41	60	10	16.7%	8	1	0.0%
42	81	12	14.8%	15	3	0.0%
43	95	13	13.7%	17	3	0.0%
44	115	21	18.3%	23	2	0.0%
45	140	28	20.0%	30	5	0.0%
46	126	27	21.4%	33	4	0.0%
47	140	27	19.3%	54	17	0.0%
Subtotal	904	159	17.6%			
48	142	33	23.2%	65	20	30.8%
49	154	44	28.6%	98	24	24.5%
50	145	55	37.9%	113	30	26.5%
51	140	36	25.7%	122	36	29.5%
52	126	33	26.2%	153	32	20.9%
53	145	52	35.9%	166	37	22.3%
54	131	31	23.7%	181	44	24.3%
55	109	40	36.7%	194	43	22.2%
56	130	37	28.5%	182	44	24.2%
57	103	30	29.1%	172	33	19.2%
Subtotal	1,325	391	29.5%			
58	99	24	24.2%	186	35	18.8%
59	76	14	18.4%	137	31	22.6%
				1,955	445	22.8%
60	66	17	25.8%	112	21	18.8%
61	68	13	19.1%	94	15	16.0%
62	54	11	20.4%	72	4	5.6%
63	55	6	10.9%	60	7	11.7%
64	49	4	8.2%	45	7	15.6%
65	37	8	21.6%	52	7	13.5%
66	31	6	19.4%	24	2	8.3%
67	29	5	17.2%	26	4	15.4%
68	35	9	25.7%	17	0	0.0%
69	18	2	11.1%	15	2	13.3%
70	25	5	20.0%	11	1	9.1%
71	15	1	6.7%	4	0	0.0%
72	6	2	33.3%	6	0	0.0%
73	9	2	22.2%	3	1	33.3%
74	6	0	0.0%	0	0	0.0%
75	5	0	0.0%	2	0	0.0%
76	5	1	20.0%	0	0	0.0%
77	4	0	0.0%	1	0	0.0%
78	1	0	0.0%	0	0	0.0%
79	4	0	0.0%	0	0	0.0%
Subtotal	697	130	18.7%	544	71	13.1%
TOTAL	2,926	680	23.2%	2,499	516	20.6%

Appendix Table A-16. Daily summary of the numbers of coho salmon tagged in the lower Skagit River and recovered during in-sample surveys, by sex, release condition, and maturity classification, 1987.

	SEX				CONDITION						MATURITY					
	Male		Female		x-		x		x+		Bright		Blush		Dark	
Date	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.	Rel.	Rec.
3-Sep	1	0	2	0	1	0	2	0	0	0	3	0	0	0	0	0
4-Sep	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0
8-Sep	15	1	7	0	1	0	20	1	1	0	22	1	0	0	0	0
10-Sep	53	6	29	3	5	2	71	7	6	0	82	9	0	0	0	0
11-Sep	44	5	15	0	7	0	51	5	1	0	59	5	0	0	0	0
14-Sep	14	2	10	1	3	0	19	3	2	0	24	3	0	0	0	0
15-Sep	54	11	31	3	3	0	79	14	3	0	85	14	0	0	0	0
17-Sep	112	17	68	10	17	2	159	24	4	1	180	27	0	0	0	0
18-Sep	103	17	46	6	15	2	134	21	0	0	149	23	0	0	0	0
21-Sep	83	11	39	4	18	1	104	14	0	0	122	15	0	0	0	0
22-Sep	123	22	48	8	15	3	156	27	0	0	171	30	0	0	0	0
25-Sep	167	39	88	21	12	2	243	58	0	0	254	60	1	0	0	0
29-Sep	80	14	59	16	3	0	136	30	0	0	137	30	2	0	0	0
1-Oct	131	41	79	13	6	2	204	52	0	0	207	54	3	0	0	0
2-Oct	128	34	92	18	11	7	209	45	0	0	210	51	10	1	0	0
5-Oct	161	42	117	23	11	2	267	63	0	0	270	64	8	1	0	0
6-Oct	66	12	53	10	6	0	113	22	0	0	110	22	9	0	0	0
8-Oct	89	28	73	15	7	2	155	41	0	0	139	36	23	7	0	0
9-Oct	272	71	301	64	10	2	563	133	0	0	549	126	22	8	2	1
12-Oct	87	22	78	12	6	2	159	32	0	0	140	26	23	8	2	0
16-Oct	77	19	78	19	2	0	153	38	0	0	129	33	25	4	1	1
19-Oct	71	22	79	16	6	0	144	38	0	0	99	22	51	16	0	0
20-Oct	52	12	69	17	0	0	121	29	0	0	93	22	28	7	0	0
23-Oct	97	32	108	34	4	1	201	65	0	0	161	54	42	10	2	2
26-Oct	33	10	24	6	3	1	54	15	0	0	27	7	27	8	3	1
27-Oct	9	3	14	5	0	0	23	8	0	0	12	4	9	4	2	0
29-Oct	15	5	24	7	1	0	38	12	0	0	24	7	13	5	2	0
30-Oct	54	14	34	8	1	1	87	21	0	0	37	14	51	8	0	0
2-Nov	254	80	317	61	9	3	562	138	0	0	106	22	434	113	31	6
3-Nov	82	26	111	28	1	0	192	54	0	0	101	30	82	22	10	2
4-Nov	48	9	36	8	1	0	83	17	0	0	12	2	41	9	31	6
6-Nov	32	0	28	6	0	0	60	6	0	0	13	2	34	3	13	1
10-Nov	82	13	84	18	2	0	164	31	0	0	37	6	108	21	21	4
12-Nov	115	20	117	27	3	0	229	47	0	0	76	15	122	28	34	4
13-Nov	111	20	132	29	3	0	240	49	0	0	53	12	162	32	28	5
18-Nov	5	0	3	0	0	0	8	0	0	0	1	0	3	0	4	0
19-Nov	2	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0
20-Nov	4	0	5	0	0	0	9	0	0	0	1	0	7	0	1	0
Total	2,926	680	2,499	516	193	35	5,214	1,160	18	1	3,896	848	1,340	315	189	33
% Recovered		23.2		20.6		18.1		22.2		5.6		21.8		23.5		17.5

Appendix Table A-17. Summary of the estimated number of tags from areas downstream of the tagging area in the lower Skagit River, 1987.

A. Downstream commercial fishery and test fishery catches.

Area	Catch[a] Before Tagging	Catch After Tagging	Number of Fish Examined	Number of Tags Found	Estimated Total Tags Present
8E	0	0	0		
8	201	1,064	0		
78C	2,085	4,244	0		
Test Fishery[b]	0	1,366	1,360	3	
Total	2,286	6,674	1,360	3	14.7

[a] Catches prior to tagging not included in tag recovery expansions.

[b] Test fisheries at Area 2, Blakes, Bay, and Jetty.

B. Out-of-system recoveries.

Location	Number of Tags Found	Estimated Total Tags Present	Comments
Area 8A or 10 commercial fishery	1	1.0	Voluntary recovery.
Lummi Sea Ponds	1	2.2	One tag observed in 1,820 fish sampled from a total rack return of 4,001 adult coho salmon.
Similk Bay commercial fishery	1	1.0	Voluntary recovery.
Oak Harbor sport fishery	1	1.0	Voluntary recovery.
Total	4	5.2	

C. Downstream spawning areas (redd data from Conrad et al. [1993]).

Area	Estimated Number of Redds	Estimated Number of Fish/Redd	Estimated Total Escapement	Number of Fish Examined	Number of Tags Found	Estimated Total Tags Present
Carpenter	874	1.5	1,311	349	0	
Nookachamps	2,226	1.5	3,339	1,159	8	
Total	3,100	1.5	4,650	1,508	8	24.7

APPENDIX B

Details of abundance estimates generated for 1987.

APPENDIX B

RECOVERY LOCATION: Marblemount Hatchery

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Normal Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 5,425
Number of Fish Examined for Tags = 29,277
Number of Tagged or Marked Fish Recovered = 962

RECOVERY LOCATION: Baker River Trap

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Normal Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 5,425
Number of Fish Examined for Tags = 4,076
Number of Tagged or Marked Fish Recovered = 111

RECOVERY LOCATION: Marblemount-Baker Pooled

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Normal Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 5,425
Number of Fish Examined for Tags = 33,353
Number of Tagged or Marked Fish Recovered = 1,073

APPENDIX B

RECOVERY LOCATION: Middle Skagit Sub-basin

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Normal Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 5,425
Number of Fish Examined for Tags = 1,497
Number of Tagged or Marked Fish Recovered = 51

RECOVERY LOCATION: Suiattle Sub-basin

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 5,425
Number of Fish Examined for Tags = 1,051
Number of Tagged or Marked Fish Recovered = 38

RECOVERY LOCATION: Upper Sauk Sub-basin

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 5,425
Number of Fish Examined for Tags = 522
Number of Tagged or Marked Fish Recovered = 18

APPENDIX B

RECOVERY LOCATION: Middle Skagit-Upper Sauk-Suiattle Pooled

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Normal Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 5,425
Number of Fish Examined for Tags = 3,070
Number of Tagged or Marked Fish Recovered = 107

RECOVERY LOCATION: Commercial Fishery

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 5,425
Number of Fish Examined for Tags = 754
Number of Tagged or Marked Fish Recovered = 24

RECOVERY LOCATION: Cascade Sub-basin

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Poisson Approximation

TAG RELEASE AND RECOVERY SUMMARY:
Number of Tags Released = 5,425
Number of Fish Examined for Tags = 597
Number of Tagged or Marked Fish Recovered = 9

APPENDIX B

RECOVERY LOCATION: Marblemount-Baker-Middle Skagit-Upper Sauk-Suiattle-Commercial Fishery Pooled

ESTIMATION METHOD: Petersen

95% CONFIDENCE INTERVAL: Normal Approximation

TAG RELEASE AND RECOVERY SUMMARY:

Number of Tags Released = 5,425
Number of Fish Examined for Tags = 37,177
Number of Tagged or Marked Fish Recovered = 1,204

RECOVERY LOCATION: Upper Skagit Sub-basin

ESTIMATION METHOD: Darroch

TAG RELEASE AND RECOVERY SUMMARY:

RELEASE STRATA	RECOVERY STRATA			Number Not Recovered	Number Tagged	Percent Recovered
	16-Nov to 8-Dec	9-Dec to 9-Feb	Total			
3 Sep - 20 Oct	10.6	38.0	48.6	3,396.4	3,445	1.4%
23 Oct - 20 Nov	3.4	23.0	26.4	1,953.6	1,980	1.3%
Number Tagged	14.0	61.0	75.0	5,350.0	5,425	1.4%
Number Untagged	102	1,705	1,807			
Number Examined	116	1,766	1,882			
Percent Tagged	12.1%	3.5%	4.0%			

RECOVERY LOCATION: Middle Sauk Sub-basin

ESTIMATION METHOD: Darroch

TAG RELEASE AND RECOVERY SUMMARY:

RELEASE STRATA	RECOVERY STRATA			Number Not Recovered	Number Tagged	Percent Recovered
	18-Nov to 18-Dec	22-Dec to 10-Feb	Total			
3 Sep - 18 Sep	1.6	0.0	1.6	603.4	605	0.3%
21 Sep - 9 Oct	14.4	9.3	23.7	2,225.3	2,249	1.1%
12 Oct - 20 Nov	0.0	16.7	16.7	2,554.3	2,571	0.6%
Number Tagged	16.0	26.0	42.0	5,383.0	5,425	0.8%
Number Untagged	433	1,421	1,854			
Number Examined	449	1,447	1,896			
Percent Tagged	3.6%	1.8%	2.2%			

CONSTRAINT MATRIX:

1	0	-1
0.33	0.33	0.33

RECOVERY LOCATION: Lower Sauk Sub-basin

ESTIMATION METHOD: Darroch

TAG RELEASE AND RECOVERY SUMMARY:

RELEASE STRATA	RECOVERY STRATA			Number Not Recovered	Number Tagged	Percent Recovered
	30-Nov to 24-Dec	29-Dec to 8-Feb	Total			
3 Sep - 18 Sep	1.4	0.0	1.4	603.6	605	0.2%
21 Sep - 9 Oct	4.3	2.3	6.6	2,242.4	2,249	0.3%
12 Oct - 30 Oct	3.0	1.2	4.2	998.8	1,003	0.4%
2 Nov - 20 Nov	4.3	3.5	7.8	1,560.2	1,568	0.5%
Number Tagged	13.0	7.0	20.0	5,405.0	5,425	0.4%
Number Untagged	175	578	753			
Number Examined	188	585	773			
Percent Tagged	6.9%	1.2%	2.6%			

CONSTRAINT MATRIX:

1	-1	0	0
0.25	0.25	0.25	0.25